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NEW CRINOID FAUNA, MISSISSIPPIAN, LODGEPOLE FORMATION, MONTANA

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ABSTRACT—Thirty-two species of crinoids, distributed among 22 genera, are recognized in the Lodgepole (Mississippian, Kinderhookian) fauna of Montana. The previously known species are: *Goniocrinus sculptilis* Miller and Gurley, *Hypselocrinus maccabei* (Miller and Gurley), *Holcocrinus longicirrifer* (Wachsmuth and Springer), *Eutaxocrinus montanensis* Springer, *Rhodocrinites douglassi* (Miller and Gurley), *Rhodocrinites cirrusi* Laudon, Parks, and Spreng, *Cribanocrinus watersianus* (Wachsmuth and Springer), *Aorocrinus douglassi* (Miller and Gurley), *Cactocrinus arnoldi* Wachsmuth and Springer, *Cactocrinus nodobrachiatus* Wachsmuth and Springer, *Cactocrinus ornatissimus* Wachsmuth and Springer, *Platycrinites bozemanensis* (Miller and Gurley), *Platycrinites incomptus* White, *Dichocrinus bozemanensis* (Miller and Gurley), *Dichocrinus campto* Laudon, and *Dichocrinus douglassi* (Miller and Gurley). Two new genera, *Bridgerocrinus* with *B. fairyensis*, n. gen. and n. sp., as the genotype, and *Abactinocrinus* with *A. rossei*, n. gen. and n. sp., as the genotype are recognized. The following new species are described: *Cradeocrinus dendratus, Culmicrinus jeffersonensis, Dinotocrinus logani, Linocrinus wilsallensis, Ramulocrinus livingstonensis, Amphelecrinus madisonensis, Amphelecrinus sacculatus, Rhodocrinites macrotumidus, Rhodocrinites priminodosus, Batocrinus gallatinensis, Platycrinites canadensis, Platycrinites basicranialus,* and *Dichocrinus quadriceptatus*. Four other genera, *Cyathocrinites, Pelecocrinus, Periechocrinites,* and *Actinocrinites* are recognized but not specifically identified.

INTRODUCTION

THE presence of excellently preserved fossil crinoids in the Lodgepole formation of Montana was called to our attention by Harold W. Scott (University of Illinois) during 1935 when a considerable collection was sent to the senior writer for study.

Careful check of the exposures located by Scott during ensuing summers led eventually to location of the exact strata that contained the well-preserved specimens. Comprehensive study of the area during the summer of 1950 by members of the University of Wisconsin summer field party resulted in the accumulation of several thousand specimens.

A grant of funds was made available by the Wisconsin Alumni Research Foundation for continued work during the summer of 1951. The Little Belt Mountains, the Big Snowy Mountains, and the Tobacco Root Mountains were also included in this work. Additional excellent materials were obtained, particularly from the Big Snowy Mountains.

The unusual set of structural and erosional conditions found in the Bridger range

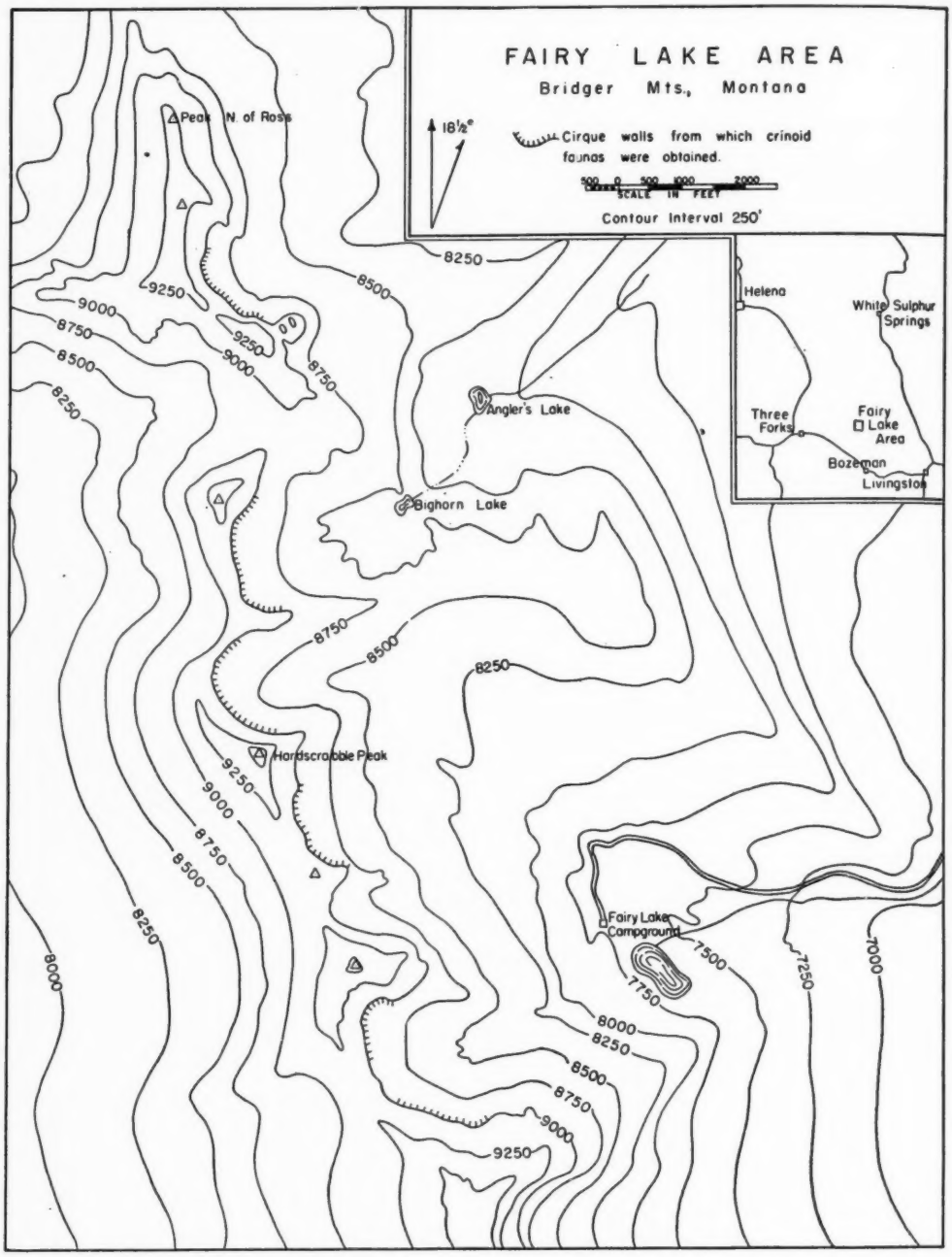

FIG. 1—Showing location of cirques from which crinoid faunas were obtained.

of Montana has made possible unusual fossil collecting conditions. The Mississippian strata form the highest and most resistant part of the range and dip steeply to the east, parallel to the strike of the range, often at angles of as much as 75 degrees. A series of Pleistocene glaciers cut deep cirques into the east side of the range often entirely dissecting the Mississippian strata. Subsequent erosion at the head of the amphitheaters has exposed wide bedding plane surfaces on the dipping strata. The fossils are removed from these surfaces only with the aid of a chisel.

Fossil crinoids occur throughout the Lodgepole formation in Montana but are best collected in very special areas in marine cycles that are developed within the formation and elsewhere in the formation as a whole. In general, most abundant fossils are available in the middle part of the formation. The more resistant, crystalline, less silty, basal ledges contain an abundance of fragmental fossils but few excellently preserved specimens. The more massive fragmental, shallow-water beds also increase in thickness in the upper part of the formation which results in fewer well-preserved fossils.

A large part of the Lodgepole formation in Montana consists of relatively thin-bedded, very nodular, black, somewhat silty limestone beds that rhythmically alternate with much thinner beds of soft silty dolomite that weather brown on the outcrop. The excellently preserved fossils invariably are found embedded in these thin, soft, silty, brown, dolomite beds. Since these beds are potential zones of weakness in the steeply dipping section in the Bridger Mountains, vast expanses of these brown, weathered beds have been exposed along the amphitheater walls.

In addition to the minor rhythmic alternations, larger marine cycles are excellently developed within the Lodgepole formation. They consist in part of a shallow water unit composed almost wholly of fragmental, crinoidal, skeletal parts. The bed as a whole is unusually light gray to light tan in color, and is harder than overlying and underlying strata, making a conspicuous projecting ledge. The shallow water fragmental beach units are thin in the lower part of the Lodgepole formation and in general increase in thickness upward in the section. In the overlying Mission Canyon formation they form massive escarpments separated by weakly developed, softer, deeper water units. The shallow water units grade imperceptibly both upward and downward into the deep water units which consist of relatively thin bedded, very nodular, black limestone beds separated by the soft thin silty brown dolomite beds. They are darkest in color in the deepest part of the unit. The thin separating dolomite beds in particular become more conspicuously brown in color as the shallow water unit is approached. The excellently preserved crinoids occur most abundantly in the beds immediately above and below the shallow water fragmental unit. Most commonly they are found within two feet on either side of the fragmental bed. This would appear to indicate that these crinoids were definitely shallow water forms, perhaps living most abundantly just outside the surf zone. The fact that the shallow water zone is made up almost entirely of fragmental skeletal parts of crinoids indicates that after death they were probably carried by longshore currents up into the beach zone.

Analysis of the Lodgepole crinoid fauna and associated invertebrates indicates Kinderhookian age for the formation. The Lodgepole and overlying Mission Canyon formations are believed to represent continuous uninterrupted marine deposition through all of Kinderhookian and perhaps approaching earliest Osagean in the upper part of the Mission Canyon formation.

Since it is rare that any two individuals of a crinoid species appear to be identical, and since evolution and time are continuous, the limits of the species are left entirely to the expansive or conservative whims of the individual worker. Hence the limits of one species with respect to another direct line descendant are subject to infinitely varying interpretation. The value of such interpretation both biologically and stratigraphically is closely related to the varying extent of the experience of the interpreter but even here is subject to the innermost egocentric tendencies of the individual concerned. Hence it can be seen that a great proportion of the sometimes seemingly hopeless confusion that now surrounds the science of biologic paleontology is largely human, man made, and biologic in itself.

Since identification of fossil remains is subject to the variation of present human interpretation as well as the original, incomplete, often erroneous interpretation and unsatisfactory illustration, presentation of fossil lists represents only an interpretation based on the experience and judgment of the interpreter. Lists of fossils without illustrations are often more misleading than valuable.

The fossils, other than echinoderms, in the Lodgepole fauna based on our best judgment after direct comparison with other faunas collected mainly from the Mississippi Valley area can be expressed as follows.

By far the most abundant elements are brachiopods with small spiriferoid and productid forms predominating. Most common are a large assemblage of forms related to *Spirifer platynotus* Weller. Faunas characterized by this assemblage of spiriferoid brachiopods have been commonly referred to in the literature as the *Spirifer centronatus* fauna. Associated with the *Spirifer platynotus* type but occurring less commonly are species that can be compared closely with *Spirifer latior* Swallow, *Spirifer biplicoides* Weller, and *Spirifer stratiformis* Meek.

Among the productid brachiopods occur varied forms closely related to *Dictyoclostus arcuatus* (Hall). One has been called *Dictyoclostus gallatinensis* (Girty). Within this group are forms representing stages of evolution between *D. arcuatus* (Hall) and *D. fernglenensis* (Weller). Also present but far less common are forms that can be compared with *Avonia newarkensis* Moore, *Linoproductus ovatus* Hall, and a very primitive form tentatively referred to *Echinoconchus*.

The strophomenid brachiopods are represented by an abundant form that perhaps was ancestral to *Streptorhynchus tenuicostatum* Weller. Also present are two species of *Schellwienella*, one closely related to *S. tenulicostata* Weller and one species of *Schuchertella*.

The rhynchonellid brachiopods were not sectioned, hence tentative identifications made for this study are without much value. Forms externally resembling *Camarotoechia tuta* (Miller) and *Rhynchopora hamburgensis* Weller occur abundantly. Two specimens of *Axiodaeneia platypleura* Clark, whose external appearance is so striking as to essentially prohibit misinterpretation, are present in our collections.

The athyrid brachiopods are represented by varied forms referable to the genus *Cliothyridina*. They range in size and shape from types similar to *C. tenuilineata* (Rowley) to large forms comparable to *C. incrassata* (Hall). No specimens referable to the large Osagean *C. obmaxima* (McChesney) have been found in the Lodgepole fauna.

The orthid brachiopods are similarly diverse. Some can be compared closely to *Schizophoria chouteauensis* Weller. A single species of *Chonetes* related to *C. multicosta* Winchell is present.

Fossils other than brachiopods occur more rarely, small zaphrentoid corals being most common. Several species of *Syringopora* are present, as are *Michelinia* and *Aulopora*. Fenestrate bryozoans and pinnaporid bryozoans are abundant. Capulid gastropods are abundant in the crinoid-bearing strata. Among the trilobites are species referable to *Phillipsia* and *Proetus*.

Analysis of the Lodgepole fauna based on these relationships shows almost none of the larger, more specialized Osage forms. With few exceptions the fauna is closely related to known Mississippi Valley Kinderhookian species.

A single composite detailed section (figs. 2a–d) measured along the cirque wall on the north side of Sacajawea Peak immediately above Fairy Lake is presented for the purpose of locating the crinoid-bearing zones within the section. A detailed location map of the Fairy Lake area in the Bridger Mountains is also presented for location of the strata containing crinoids within the area (fig. 1).

The preponderance of the crinoid fauna was collected within a few feet both above and below the terminal beds in the first three megacycles as shown in the section. The "upper crinoid zone, Fairy Lake area" referred to in the text contains some 10 feet of strata immediately below the terminal bed of megacycle 3.

Well-preserved crinoids are found associated closely with the terminal beds of megacycles up to the shaly dolomites both

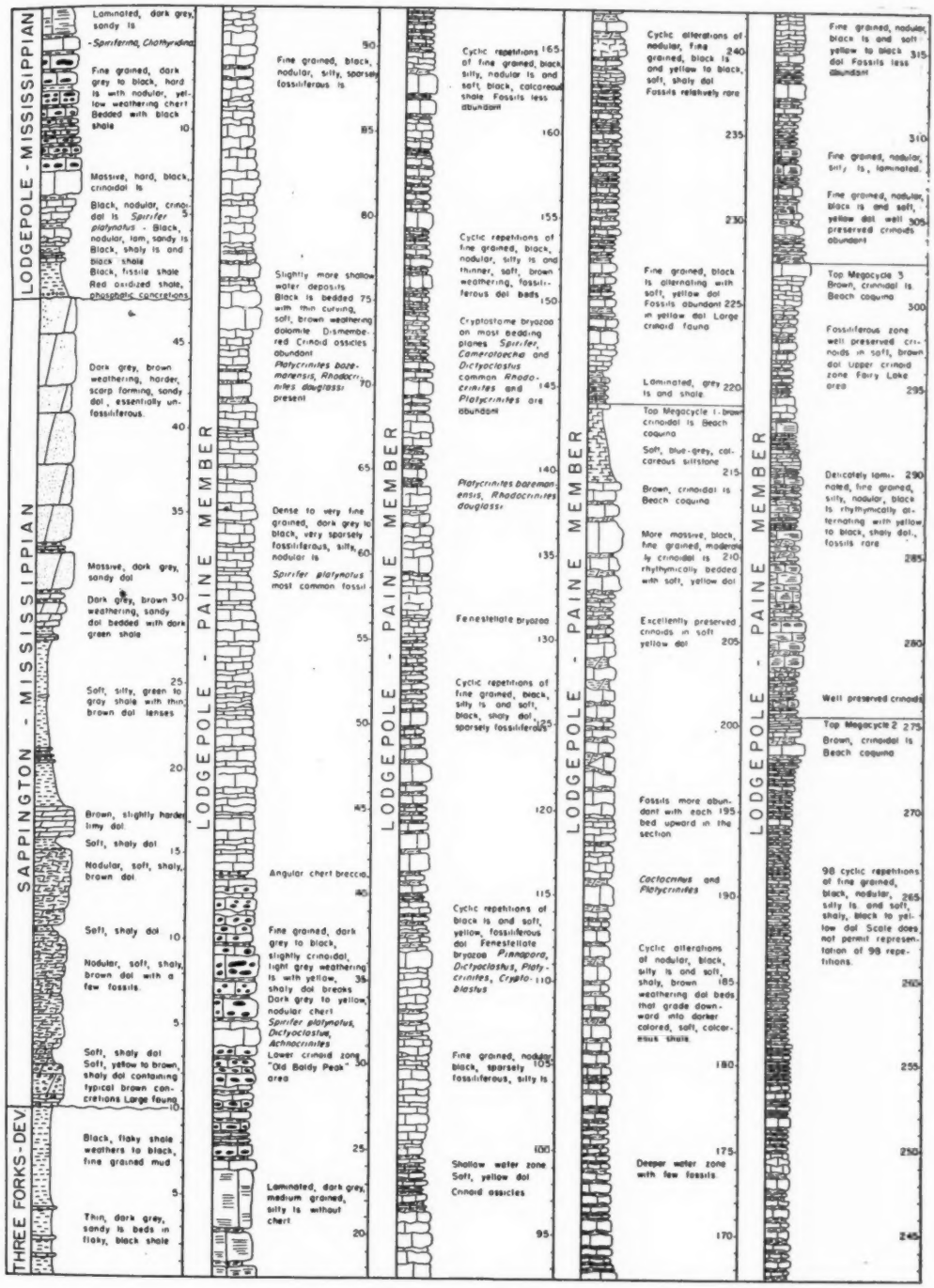
THREE FORKS - DEV
SAPPINGTON - MISSISSIPPIAN
LODGEPOLE - MISSISSIPPIAN
LODGEPOLE - PAINE MEMBER
Laminated, dark grey, sandy ls
-Spiriferina, Clothyridina
Fine grained, dark grey to black, hard ls with nodular, yellow weathering chert Bedded with black shale
Massive, hard, black, crinoidal ls
Black, nodular, crinoidal ls Spirifer platynotus - Black, nodular, tan, sandy ls Black, shaly ls and black shale Black, fissile shale Red oxidized shale, phosphatic concretions
Dark grey, brown weathering, harder, scarp forming, sandy dol, essentially unfossiliferous.
Massive, dark grey, sandy dol
Dark grey, brown weathering, sandy dol bedded with dark green shale
Soft, silty, green to gray shale with thin brown dol lenses
Brown, slightly harder limy dol
Soft, shaly dol
Nodular, soft, shaly, brown dol
Soft, shaly dol
Nodular, soft, shaly, brown dol with a few fossils.
Soft, shaly dol
Soft, yellow to brown, shaly dol containing typical brown concretions Large fauna
Black, flaky shale weathers to black, fine grained mud
Thin, dark grey, sandy ls beds in flaky, black shale
Fine grained, black, nodular, silty, sparsely fossiliferous ls
Slightly more shallow water deposits Black ls bedded with thin curving, soft, brown weathering dolomite Dismembered Crinoid ossicles abundant Platycrinites bataemensis, Rhodocrinites douglassi present
Dense to very fine grained, dark grey to black, very sparsely fossiliferous, silty, nodular ls Spirifer platynotus most common fossil
Angular chert breccia.
Fine grained, dark grey to black, slightly crinoidal, light grey weathering ls with yellow, shaly dol breaks Dark grey to yellow, nodular chert Spirifer platynotus, Dictyoclostus, Achoncrinites
Lower crinoid zone "Old Baldy Peak" area
Laminated, dark grey, medium grained, silty ls without chert
Cyclic repetitions of fine grained, black, silty, nodular ls and soft, black, calcareous shale Fossils less abundant
Cyclic repetitions of fine grained, black, nodular, silty ls and thinner, soft, brown weathering, fossiliferous dol beds
Cryptostome bryozoa on most bedding planes Spirifer, Camerotoechia and Dictyoclostus common Rhodocrinites and Platycrinites are abundant
Platycrinites bataemensis, Rhodocrinites douglassi
Fenestellate bryozoa
Cyclic repetitions of fine grained, black, silty ls and soft, black, shaly dol, sparsely fossiliferous
Cyclic repetitions of black ls and soft, yellow, fossiliferous dol Fenestellate bryozoa Pinnatopora, Dictyoclostus, Platycrinites, Cryptoblastus
Fine grained, nodular, black, sparsely fossiliferous, silty ls
Shallow water zone Soft, yellow dol Crinoid ossicles
Cyclic alterations of nodular, fine grained, black ls and yellow to black, soft, shaly dol Fossils relatively rare
Fine grained, black ls alternating with soft, yellow dol Fossils abundant in yellow dol Large crinoid fauna
Laminated, grey ls and shale
Top Megacycle 1 - brown crinoidal ls Beach coquina
Soft, blue-grey, calcareous siltstone
Brown, crinoidal ls Beach coquina
More massive, black, fine grained, moderately crinoidal ls rhythmically bedded with soft, yellow dol
Excellently preserved crinoids in soft yellow dol
Fossils more abundant with each bed upward in the section
Coeliocrinus and Platycrinites
Cyclic alterations of nodular, black, silty ls and soft, shaly, brown weathering dol beds that grade downward into darker colored, soft, calcareous shale
Deeper water zone with few fossils
Fine grained, nodular, black ls and soft yellow to black dol Fossils less abundant
Fine grained, nodular, silty ls, laminated.
Fine grained, nodular, black ls and soft, yellow dol well preserved crinoids abundant
Top Megacycle 3 Brown, crinoidal ls Beach coquina
Fossiliferous zone well preserved crinoids in soft, brown dol Upper crinoid zone Fairy Lake area
Delicately laminated, fine grained, silty, nodular, black ls rhythmically alternating with yellow to black, shaly dol., fossils rare
Well preserved crinoids
Top Megacycle 2 Brown, crinoidal ls Beach coquina
98 cyclic repetitions of fine grained, black, nodular, silty ls and soft, shaly, black to yellow dol Scale does not permit representation of 98 repetitions.

FIG. 2a—Fairy Lake Section, Part 1.

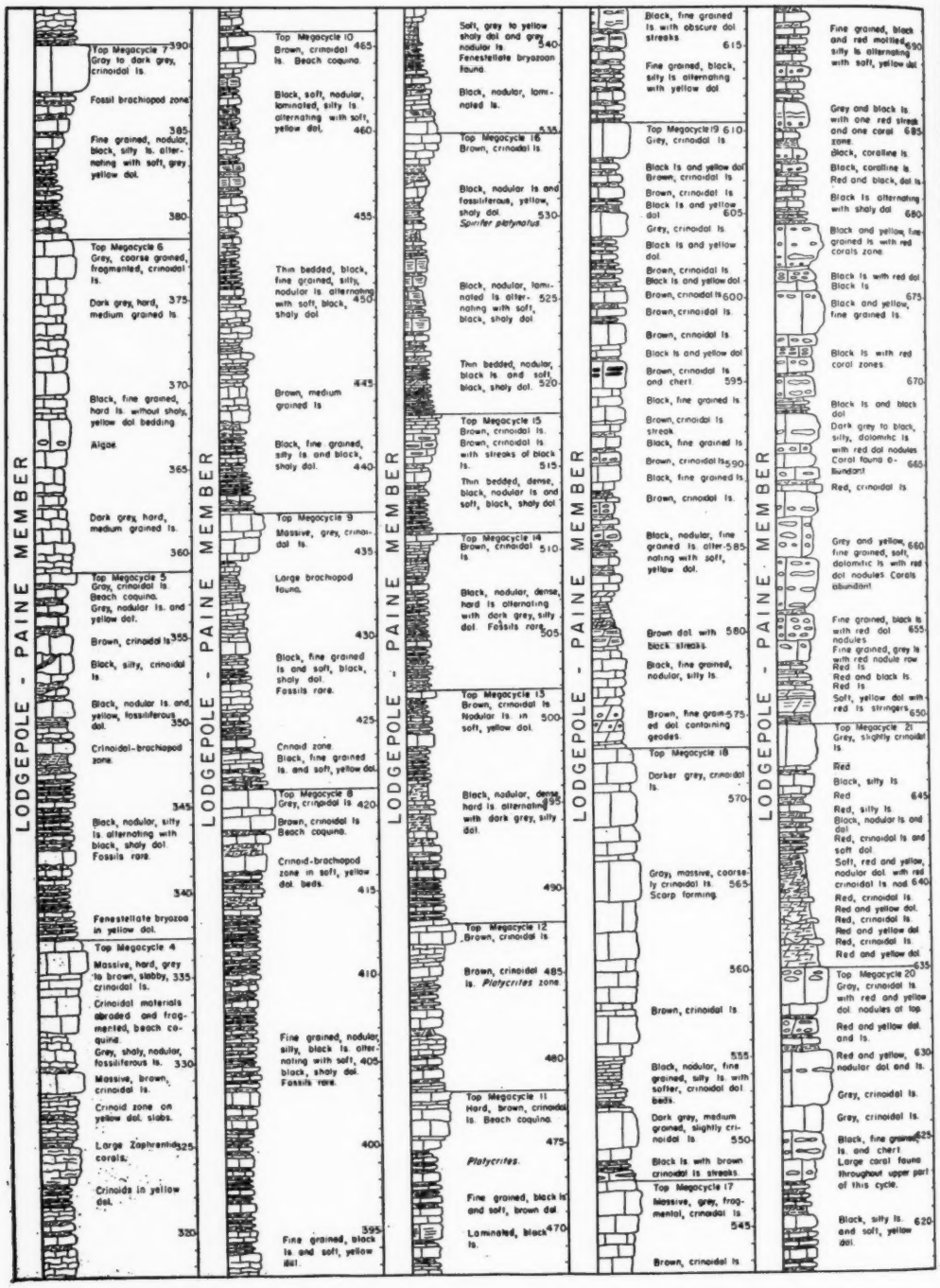
LODGEPOLE - PAINE MEMBER
Top Megacycle 7
Gray to dark grey, crinoidal ls.
Fossil brachiopod zone
Fine grained, nodular, black, silty ls. alternating with soft, grey yellow dol.
Top Megacycle 6
Grey, coarse grained, fragmented, crinoidal ls.
Dark grey, hard, medium grained ls.
Black, fine grained, hard ls. without shaly, yellow dol. bedding.
Algae
Dark grey, hard, medium grained ls.
Top Megacycle 5
Gray, crinoidal ls. Beach coquina. Grey, nodular ls. and yellow dol.
Brown, crinoidal ls.
Black, silty, crinoidal ls.
Black, nodular ls. and yellow, fossiliferous dol.
Crinoidal-brachiopod zone.
Black, nodular, silty ls. alternating with black, shaly dol. Fossils rare.
Fenestellate bryozoa in yellow dol.
Top Megacycle 4
Massive, hard, grey to brown, slabby, crinoidal ls.
Crinoidal materials abraded and fragmented, beach coquina.
Grey, shaly, nodular, fossiliferous ls.
Massive, brown, crinoidal ls.
Crinoid zone on yellow dol. slabs.
Large Zaphrentis corals.
Crinoids in yellow dol.
Top Megacycle 10
Brown, crinoidal ls. Beach coquina.
Black, soft, nodular, laminated, silty ls. alternating with soft, yellow dol.
Thin bedded, black, fine grained, silty, nodular ls alternating with soft, black, shaly dol
Brown, medium grained ls
Black, fine grained, silty ls. and black, shaly dol.
Top Megacycle 9
Massive, grey, crinoidal ls.
Large brachiopod fauna.
Black, fine grained ls and soft, black, shaly dol. Fossils rare.
Crinoid zone.
Black, fine grained ls. and soft, yellow dol.
Top Megacycle 8
Grey, crinoidal ls
Brown, crinoidal ls Beach coquina.
Crinoid-brachiopod zone in soft, yellow dol. beds.
Fine grained, nodular, silty, black ls. alternating with soft, black, shaly dol. Fossils rare.
Fine grained, black ls and soft, yellow dol.
Soft, grey to yellow shaly dol and grey nodular ls. Fenestellate bryozoan fauna.
Black, nodular, laminated ls.
Top Megacycle 16
Brown, crinoidal ls.
Black, nodular ls and fossiliferous, yellow, shaly dol. Spirifer pleynotus
Black, nodular, laminated ls alternating with soft, black, shaly dol.
Thin bedded, nodular, black ls. and soft, black, shaly dol.
Top Megacycle 15
Brown, crinoidal ls. Brown, crinoidal ls with streaks of black ls.
Thin bedded, dense, black, nodular ls and soft, black, shaly dol
Top Megacycle 14
Brown, crinoidal ls
Black, nodular, dense, hard ls alternating with dark grey, silty dol. Fossils rare.
Top Megacycle 13
Brown, crinoidal ls Nodular ls. in soft, yellow dol.
Black, nodular, dense, hard ls alternating with dark grey, silty dol.
Top Megacycle 12
Brown, crinoidal ls
Brown, crinoidal ls. Platycrites zone
Platycrites.
Top Megacycle 11
Hard, brown, crinoidal ls Beach coquina.
Fine grained, black ls and soft, brown dol.
Laminated, black ls.
Black, fine grained ls with obscure dol streaks
Fine grained, black, silty ls alternating with yellow dol
Top Megacycle 19
Grey, crinoidal ls.
Black ls and yellow dol
Brown, crinoidal ls
Brown, crinoidal ls
Black ls and yellow dol.
Grey, crinoidal ls.
Black ls and yellow dol.
Brown, crinoidal ls
Black ls and yellow dol
Brown, crinoidal ls
Brown, crinoidal ls
Brown, crinoidal ls
Black ls and yellow dol
Brown, crinoidal ls and chert.
Black, fine grained ls
Brown, crinoidal ls streak
Black, fine grained ls
Brown, crinoidal ls
Black, fine grained ls.
Brown, crinoidal ls.
Black, nodular, fine grained ls. alternating with soft, yellow dol.
Brown dol. with black streaks.
Black, fine grained, nodular, silty ls.
Brown, fine grained dol containing geodes.
Top Megacycle 18
Darker grey, crinoidal ls.
Gray, massive, coarsely crinoidal ls. Scarp forming.
Brown, crinoidal ls
Black, nodular, fine grained, silty ls with softer, crinoidal dol beds.
Dark grey, medium grained, slightly crinoidal ls
Black ls with brown crinoidal ls streaks
Top Megacycle 17
Massive, grey, fragmental, crinoidal ls.
Brown, crinoidal ls
Fine grained, black and red mottled, silty ls alternating with soft, yellow dol
Grey and black ls with one red streak and one coral zone
Black, coralline ls
Black, coralline ls
Red and black, dol ls
Black ls alternating with shaly dol
Black and yellow, fine grained ls with red corals zone.
Black ls with red dol
Black ls
Black and yellow, fine grained ls.
Black ls with red coral zones
Black ls and black dol
Dark grey to black, silty, dolomitic ls with red dol nodules Coral fauna fo- bundant
Red, crinoidal ls
Grey and yellow, fine grained, soft, dolomitic ls with red dol nodules Corals abundant
Fine grained, black ls with red dol nodules
Fine grained, grey ls with red nodule row
Red ls
Red and black ls.
Red ls
Soft, yellow dol with red ls stringers
Top Megacycle 21
Grey, slightly crinoidal ls
Red
Black, silty ls
Red
Red, silty ls
Black, nodular ls and dol
Red, crinoidal ls and soft dol
Soft, red and yellow, nodular dol. with red crinoidal ls nod
Red, crinoidal ls. Red and yellow dol.
Red, crinoidal ls. Red and yellow dol.
Red, crinoidal ls. Red and yellow dol.
Top Megacycle 20
Gray, crinoidal ls with red and yellow dol. nodules at top.
Red and yellow dol. and ls.
Red and yellow, nodular dol. and ls.
Grey, crinoidal ls.
Grey, crinoidal ls.
Black, fine grained ls. and chert
Large coral fauna throughout upper part of this cycle.
Black, silty ls. and soft, yellow dol.

FIG. *2b*—Fairy Lake Section, Part 2. Errata: *Platycrites* should read *Platycrinites*.

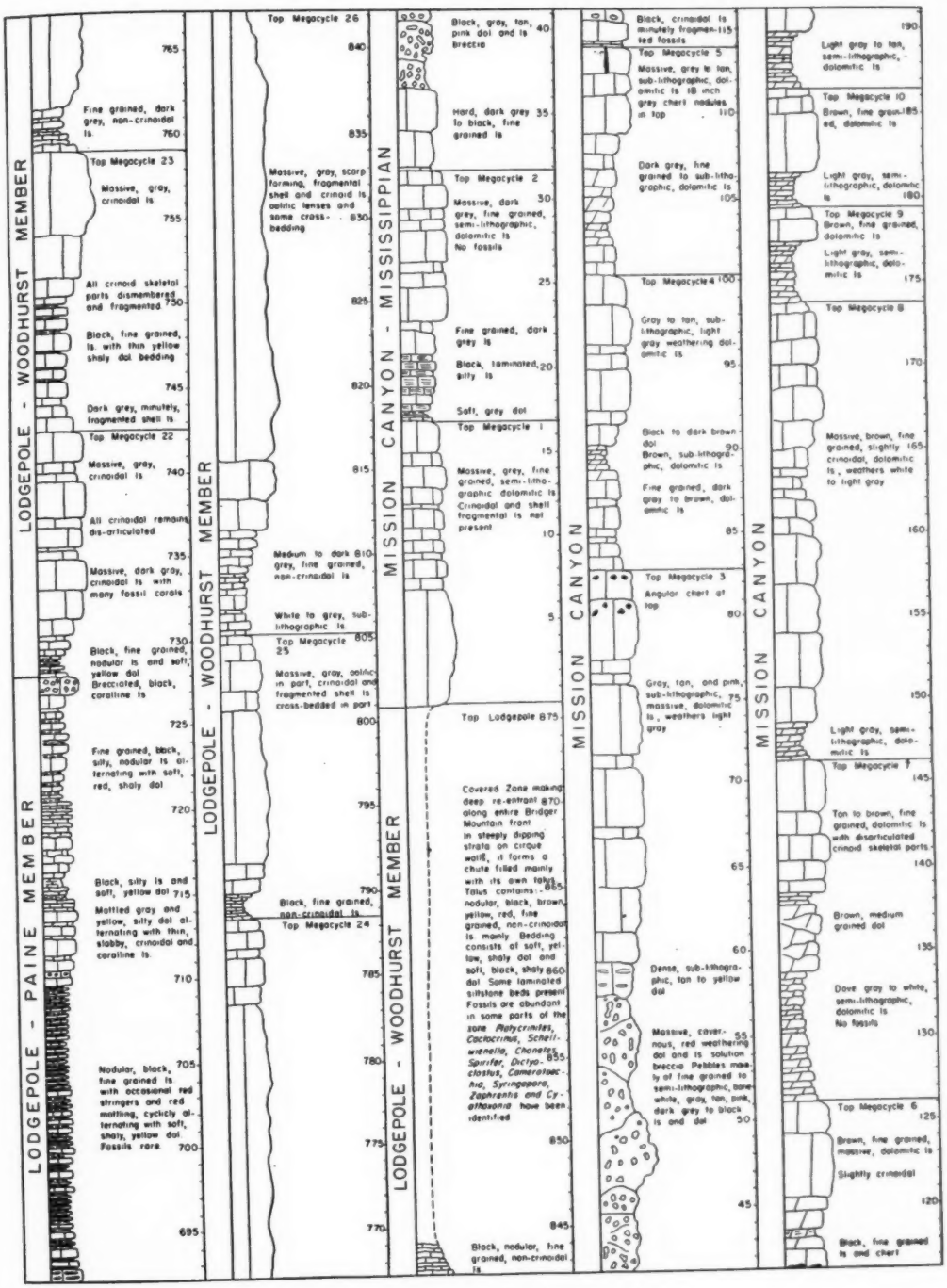
LODGEPOLE - PAINE MEMBER
LODGEPOLE - WOODHURST MEMBER
MISSION CANYON - MISSISSIPPIAN
MISSION CANYON
765
Fine grained, dark grey, non-crinoidal ls
760
Top Megacycle 23
Massive, gray, crinoidal ls
755
All crinoid skeletal parts dismembered and fragmented
750
Black, fine grained, ls with thin yellow shaly dol bedding
745
Dark grey, minutely, fragmented shell ls
Top Megacycle 22
Massive, gray, crinoidal ls
740
All crinoidal remains dis-articulated
735
Massive, dark gray, crinoidal ls with many fossil corals
730
Black, fine grained, nodular ls and soft, yellow dol
Brecciated, black, coralline ls
725
Fine grained, black, silty, nodular ls alternating with soft, red, shaly dol
720
Black, silty ls and soft, yellow dol
715
Mottled gray and yellow, silty dol alternating with thin, slabby, crinoidal and coralline ls
710
Nodular, black, fine grained ls with occasional red stringers and red mottling, cyclicly alternating with soft, shaly, yellow dol. Fossils rare
705
700
695
Top Megacycle 26
840
835
Massive, gray, scarp forming, fragmental shell and crinoid ls, oolitic lenses and some cross-bedding
830
825
820
815
Medium to dark grey, fine grained, non-crinoidal ls
810
White to grey, sub-lithographic ls
Top Megacycle 25
805
Massive, gray, oolitic in part, crinoidal and fragmented shell ls cross-bedded in part
800
795
790
Black, fine grained, non-crinoidal ls
Top Megacycle 24
785
780
775
770
Black, gray, tan, pink dol and ls breccia
40
Hard, dark grey to black, fine grained ls
35
Top Megacycle 2
Massive, dark grey, fine grained, semi-lithographic, dolomitic ls
No fossils
30
25
Fine grained, dark grey ls
Black, laminated, silty ls
20
Soft, grey dol
Top Megacycle 1
15
Massive, grey, fine grained, semi-lithographic dolomitic ls
Crinoidal and shell fragmental is not present
10
5
Top Lodgepole 875
Covered Zone making deep re-entrant 870 along entire Bridger Mountain front in steeply dipping strata on cirque wall, it forms a chute filled mainly with its own talus. Talus contains: nodular, black, brown, yellow, red, fine grained, non-crinoidal ls mainly. Bedding consists of soft, yellow, shaly dol and soft, black, shaly 860 dol. Some laminated siltstone beds present. Fossils are abundant in some parts of the zone *Platycrinites, Cactocrinus, Scheilwienella, Chonetes, Spirifer, Dictyoclostus, Camerotechno, Syringopora, Zaphrentis and Cyathaxonia* have been identified
865
855
850
845
Black, nodular, fine grained, non-crinoidal ls
Black, crinoidal ls minutely fragmented fossils
115
Top Megacycle 5
Massive, grey to tan, sub-lithographic, dolomitic ls 18 inch grey chert nodules in top
110
Dark grey, fine grained to sub-lithographic, dolomitic ls
105
Top Megacycle 4
100
Gray to tan, sub-lithographic, light gray weathering dolomitic ls
95
Black to dark brown dol
90
Brown, sub-lithographic, dolomitic ls
Fine grained, dark gray to brown, dolomitic ls
85
Top Megacycle 3
Angular chert at top
80
Gray, tan, and pink, sub-lithographic, massive, dolomitic ls, weathers light gray
75
70
65
60
Dense, sub-lithographic, tan to yellow dol
Massive, cavernous, red weathering dol and ls solution breccia. Pebbles made up of fine grained to semi-lithographic, bone white, gray, tan, pink, dark grey to black ls and dol
55
50
45
190
Light gray to tan, semi-lithographic, dolomitic ls
Top Megacycle 10
Brown, fine grained, dolomitic ls
185
Light gray, semi-lithographic, dolomitic ls
180
Top Megacycle 9
Brown, fine grained, dolomitic ls
Light gray, semi-lithographic, dolomitic ls
175
Top Megacycle 8
170
Massive, brown, fine grained, slightly crinoidal, dolomitic ls, weathers white to light gray
165
160
155
150
Light gray, semi-lithographic, dolomitic ls
Top Megacycle 7
145
Tan to brown, fine grained, dolomitic ls with disarticulated crinoid skeletal parts
140
Brown, medium grained dol
135
Dove gray to white, semi-lithographic, dolomitic ls
No fossils
130
Top Megacycle 6
125
Brown, fine grained, massive, dolomitic ls
Slightly crinoidal
120
Black, fine grained ls and chert

FIG. 2c—Fairy Lake Section, Part 3.

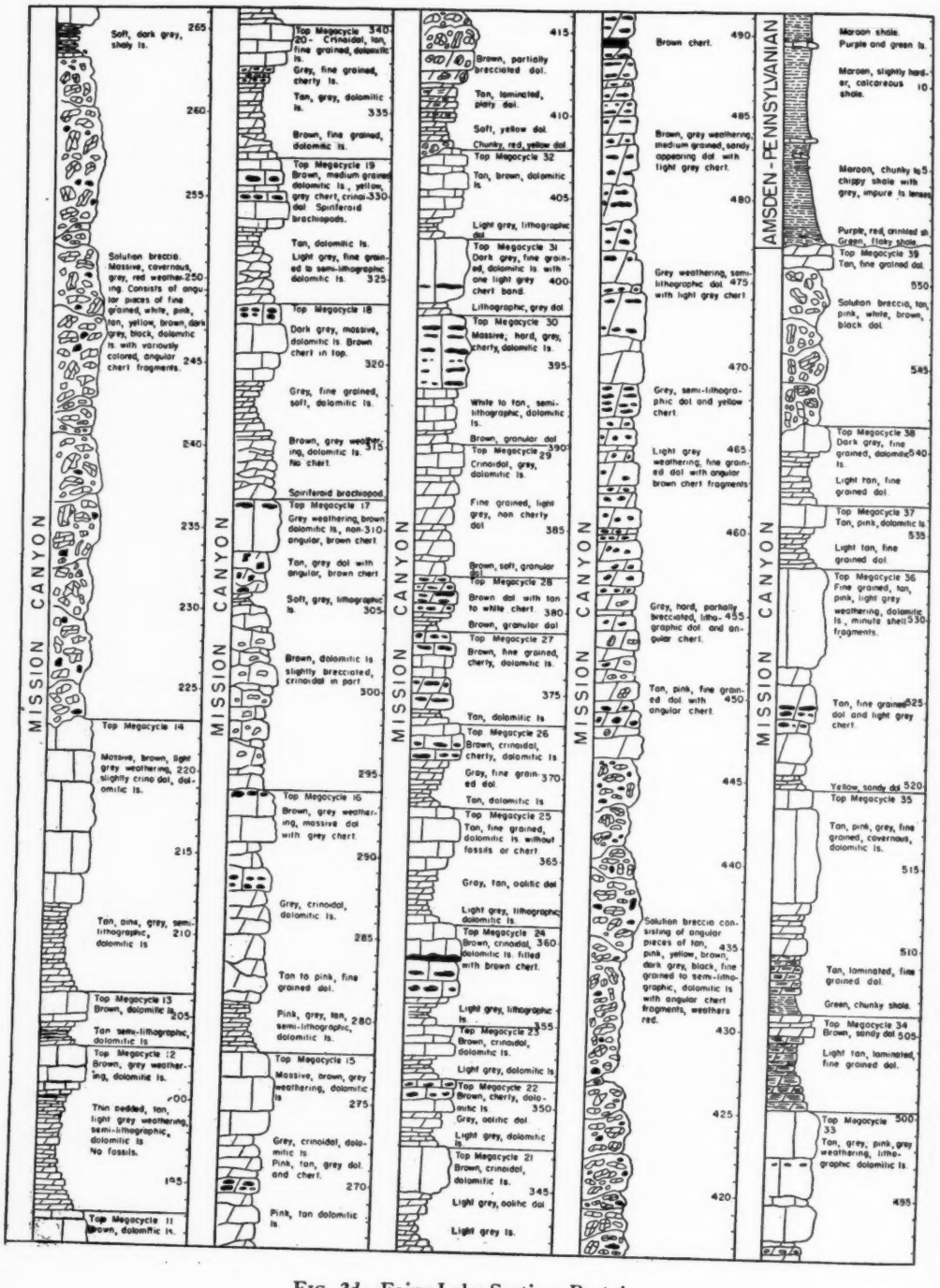

FIG. *2d*—Fairy Lake Section, Part 4.

above and below megacycle 16. Above megacycle 16 well-preserved crinoids occur only rarely. A few isolated specimens have been recovered from the red coral-bearing strata in megacycles 21 and 22.

Platycrinites bozemanensis is by far the most abundant crinoid in the Lodgepole fauna and ranks in abundance with *Spirifer platynotus*. It ranges throughout the Lodgepole formation.

Crinoids were recovered from both walls of the cirque immediately above Fairy Lake. Large collections were obtained from the walls of the two cirques located southeast and northwest of Hardscrabble Peak. A very large collection was obtained from the head end of the large cirque above Bighorn Lake. A few were collected from the large cirque wall located southeast of the peak north of Ross.

PREVIOUS WORK

Very little systematic paleontology dealing with the Crinoidea of the Mississippian rocks of western United States has been undertaken.

S. A. Miller and Wm. F. E. Gurley (1896, pp. 82–86) brought to the attention of geologists the excellently preserved crinoids of the Bridger range of Montana. Three new species were described in their paper. After further collecting they described five additional new species from the area in 1897 (Miller and Gurley, 1897, pp. 39–42).

Fossil crinoids were mentioned in stratigraphic lists presented by various workers in Mississippian rocks in Montana. Springer (1920, p. 372) described *Eutaxocrinus montanensis*, the only other crinoid species described from this area.

Closely related faunas were described by Laudon (1933, pp. 1–74), Peck (1938, pp. 70–111), and Laudon and Beane (1937, pp. 127–272) from Mississippi Valley, Kinderhookian formations.

Laudon, Parks, and Spreng (1952, p. 544) completed a manuscript describing a large excellently preserved crinoid fauna from the Banff formation of Alberta in which a number of the Lodgepole genera and species were common.

SYSTEMATIC PALEONTOLOGY

CYATHOCRINITIDAE Bassler, 1938
Genus CYATHOCRINITES Miller, 1821
CYATHOCRINITES sp.
Plate 51, figures 13–14

The genus *Cyathocrinites*, ranging as it does from Silurian through Permian rocks, has come to mean very little either stratigraphically or biologically. Even as recognized at present the number of species assigned to the genus approaches one hundred. Without extensive long term effort successful revision of the genus could not be accomplished. Rather than further complicate the literature, we illustrate the Lodgepole species for whatever stratigraphic value it may have.

Comparison of the Lodgepole species with specimens from the Banff formation of Alberta shows them to be closely related if not identical.

Occurrence.—Lodgepole formation, Bridger Range, Montana.

Figured specimens.—USNM Nos. 123145, 123146.

OTTAWACRINIDAE Moore and Laudon, 1943
CRADEOCRINUS Goldring, 1923

The genus *Cradeocrinus* was proposed by Goldring (1923, p. 347) for primitive, slender, nonpinnulate, inadunate crinoids having a steeply conical cup and a pentagonal RA in the normal advanced position resting on PB and RPB, laterally in contact with X and RPR and in contact above with Rt. Because of the nonpinnulate arms, *Cradeocrinus* was referred by Goldring to the Cyathocrinitidae. We are assigning *Cradeocrinus* to the Ottawacrinidae because we believe that it descended directly from the Ottawacrinidae by slight migration of the RA upward to make it pentagonal and bring it in contact with Rt. *Cradeocrinus* is assumed to have descended from some form closely related to *Lasiocrinus* and differs from *Lasiocrinus* only in that it has the advanced pentagonal RA instead of the more primitive, quadrangular RA that characterizes *Lasiocrinus*.

The known range of *Cradeocrinus* at present is from Upper Devonian (Portage, New York) to Lower Mississippian, Kinderhookian beds.

CRADEOCRINUS DENDRATUS
Laudon and Severson, n. sp.
Plate 51, figures 9–12; plate 55, figures 3–4

Cradeocrinus dendratus is a slender, delicate species with the arms apparently tending to constrict at the mid-length, flare in the upper part and finally recurve at the tips.

Cup steeply conical, elongated, 4.5 mm. long and 3 mm. wide at arm bases on holotype, 5.5 mm. high and 3.5 mm. wide on largest paratype.

IBB high, forming a conspicuous part of the cup. BB higher than wide. RR width 2 mm., height 1.5 mm. on holotype, arm facets occupy full upper width of R. IBrr three, first longer than second and third, rounded noncuneiform. Strong ramule-like branches given off from every other brachial in the lower arms and from every brachial in the upper arms. The Brr sutures are simple non-cuneiform in the lower arms and become slightly cuneiform in the upper parts of the arms.

Development of advanced evolutionary characters on the upper parts of crinoid arms can be observed in most crinoids. Crinoids often exhibit a complete transition from uniserial arms near the cup, through cuneiform to biserial at the tips. Immature forms often exhibit uniserial arms throughout their length and as the individuals become mature the advanced characters of cuneiform and biserial brachials gradually develop from the outer tips downward toward the cup.

X as large as RR, slightly above the line of RR, resting on the truncated upper surface of PB, RA small, pentagonal, in the normal position beneath RX. Sac long, slender, delicate, consisting of parallel rows of hexagonal plates. Upper tip not observed.

Discussion.—*Cradeocrinus dendratus*, n. sp., is closely related to *C. warreni* Laudon, Parks, and Spreng (1952, p. 551) from the Banff formation in Alberta. *C. warreni* is the only other known Mississippian species at the present time. *C. dendratus* differs from *C. warreni* in having more advanced arm structure. The arms of *C. warreni* are not cuneiform near the tips and do not develop pinnules on every brachial. *C. dendratus* differs from the two known Devonian species of *Cradeocrinus* in the same manner in that the arms of the Devonian species retain their primitive characters.

Occurrence.—Lodgepole formation, north wall of Fairy Lake cirque, approximately middle portion of the formation, Bridger Mountains, Montana. The crinoid fauna with which *C. dendratus* was associated occurs somewhat below the main crinoid bearing ledges of the Lodgepole section. All specimens were collected by H. H. Hall, Lawrence, Kansas.

Types.—Holotype, USNM No. 123142; paratypes, USNM Nos. 123141, 123143, 123144.

GONIOCRINUS Miller and Gurley, 1890
GONIOCRINUS SCULPTILIS Miller and Gurley
Plate 51, figure 22

A single small specimen of *Goniocrinus* has been recovered from the Lodgepole formation of the Bridger Mountains in Montana. It is excellently preserved so that study of most of the characters is possible. We have referred it to the LeGrand species although it is small and exhibits some minor characters which may eventually make it desirable to establish a new species.

Like other species of *Goniocrinus* the IBB are large and the BB small, the arms occupy the full upper surface of the RR, there are three or four IBrr, and the arm Brr articulate with ramule-like branches that are not present on all Brr. The distinctive, flange-like flaring character of the lower Brr that characterizes the genus *Goniocrinus* is unusually well developed in this species. This character is much more strongly developed in the Lodgepole specimen than in any other that we have observed.

Occurrence.—Lodgepole formation, upper crinoid zone, Bridger Mountains, Montana.

Figured specimen.—USNM No.123154.

BLOTHROCRINIDAE Moore and Laudon, 1943
CULMICRINUS Jaekel, 1918

The genus *Culmicrinus* was erected by Jaekel (1918, p. 62) for inadunate crinoids with steep conical cups in which the first

branching of the arms takes place above IBr2 and the arms branch more than once. On the genotype *C. regularis*, the first bifurcation of the arms is accomplished on the eighth Br. The genotype is a robust form, with strong arms, Brr slightly cuneiform with well-developed strong pinnules, a round column, and a long sac reaching well up toward and perhaps beyond the tips of the arms.

Culmicrinus apparently developed from the Ottawacrinidae by addition of pinnules to each Br of the arms. It retains the primitive steep conical cup, and the relatively high first bifurcation of the arms. Like the more primitive Ottawacrinidae the number of bifurcations in the arms of *Culmicrinus* is relatively few. The RA is pentagonal and in the normal, more advanced position, beneath Rt. *Culmicrinus* is closely related to *Blothrocrinus* and differs from it only in that the first bifurcation of the arms takes place on IBr2 in *Blothrocrinus*.

CULMICRINUS JEFFERSONENSIS
Laudon and Severson, n. sp.
Plate 51, figures 29–30; plate 55, figure 1

The Lodgepole species is represented by two specimens, both of which have the upper parts of the arms missing. The Lodgepole species is the most robust known form assigned to *Culmicrinus* thus far.

Cup steeply conical, slightly higher than wide, height 22 mm., width 21 mm. in holotype.

IBB make a conspicuous part of the cup, height 5 mm., width 6.5 mm. on holotype. BB higher than wide, slightly depressed at corners, width 9 mm., height 11 mm. in holotype, RR wider than high, width 8 mm., height 7 mm. in holotype. Radial facet slightly constricted, curved, occupying considerably over half of the upper surface of RR. X smaller than R, in normal position on truncated upper surface of PB. RA equal in size to X in normal position beneath Rt. Sac consists of vertical rows of hexagonal plates, wider than high, with a median ridge running up each row and two or three stellate ridges running laterally to the plate borders.

Arms stout, rounded, only slightly cuneiform, branching for the first time on IBr 11 or 12 in the holotype. Pinnules not observed.

Column round, of unusually thin columnals.

Discussion.—*C. jeffersonensis* is a much more rugged, massive appearing form than any other known species. It is perhaps more closely related to *C. regularis* (von Meyer) (Jaekel, 1918, p. 62), the genotype, than to any other form. It differs from *C. regularis* in that the cup of *C. regularis* is much less high in proportion to its width, the arm Brr are wider in proportion to their height, making the first branching of the arms seem to be lower in the cup and the first bifurcation of the arms takes place on IBr 8 to 10 instead of IBr 11 to 12. The relatively stellate sac of *C. regularis* is closely similar to that of *C. jeffersonensis*.

The only other species of *Culmicrinus* in any way closely related to *C. jeffersonensis* is *C. missouriensis* (Shumard) (1857, p. 80) from the St. Louis limestone. *C. missouriensis* has a steep cup and the first bifurcation of the arms takes place on IBr 13 to 16. The small, non-stellate sac plates separate *C. missouriensis* from *C. jeffersonensis* immediately.

Occurrence.—Lodgepole formation, Bridger Mountains, Montana.

Types.—Holotype, USNM No. 123162; paratype, USNM No. 123161.

PELECOCRINIDAE Kirk, 1941
PELECOCRINUS Kirk, 1941
PELECOCRINUS sp.
Plate 51, figure 15; plate 55, figure 6

The genus *Pelecocrinus* proposed by Kirk (1941a, p. 82) is characterized mainly by Burlington and Keokuk species with only one, *P. parviglyptus* (Laudon and Beane) (1937, p. 257), listed as having come from Kinderhookian beds. The Kinderhookian species while closely related to *Pelecocrinus* has arms strangely non-typical of the other species recognized within the genus.

Studies of the crinoid fauna of the Banff formation, Kinderhookian, Alberta, have brought to light a wealth of material belonging to the genus *Pelecocrinus*.

Pelecocrinus is represented by a single damaged specimen in the Lodgepole formation of Montana. Due to the unusual nature of the sac, we feel sure that a new specific

name should be proposed, but due to the incomplete nature of the single specimen in our collections, we are figuring it only, in the hopes that eventually better materials may be available for study.

The Lodgepole species has a rapidly expanding cup, X and RA in normal position, arm facets restricted, IBr one except on anterior, typical cuneiform Brr in upper arms with projecting pinnule facets. The sac is expanded in the upper portion and made of unusually small stellate plates not arranged in parallel rows. The sac is capped with a long sharp spine. This rapidly expanding sac with its minute plates is not characteristic of the other known species of *Pelecocrinus*.

Occurrence.—Lodgepole formation, Bridger Mountains, Montana.

Figured specimen.—USNM No. 123147.

DINOTOCRINUS Kirk, 1941

We were originally of the impression that the specimens which we are here referring to *Dinotocrinus* were immature individuals. However, since we have recovered some 10 specimens from several different zones within the Lodgepole formation, all small, and all of about equal size, it seems apparent that we are dealing with small adult forms.

Dinotocrinus was proposed by Kirk (1941b, p. 513) for species known only from rocks of Meramecian and early Chesteran age. The occurrence of a small, generalized species in rocks of Kinderhookian age may provide the necessary information needed to solve the evolutionary development of *Dinotocrinus*.

DINOTOCRINUS LOGANI
Laudon and Severson, n. sp.
Plate 51, figures 23–27; plate 55, figures 12–14

The crown is short and stout, arms closely abutting, and incurved at tips. The cup is rounded, broad, and abruptly truncated at the base, with the IBB not showing on the lateral wall. The cup is 4 mm. wide at arm bases and 1.5 mm. high.

IBB very small, confined to shallow basal concavity, points barely projecting beyond column. RR curving around under the base and directed slightly outward, forming approximately half of the lateral cup wall. RR approximately 1.5 mm. wide and 1 mm. high, articulating facet occupying full width of R. RA pentagonal, in normal position on PB and RPB, laterally in contact with X and RAR, supporting Rt, as large as X, slightly below the line of the RR. X in normal position on truncated upper surface of PB, apparently in sutural contact with LPR and IBr_1 in the left ray. Rt appears to be in sutural contact with RPR and IBr_1 of the right ray.

IBrr one to each ray except in the anterior where there are three, occupying full width of R facet, closely abutting except on posterior side, wider than high except for IBr_1 in anterior ray which is distinctly higher than the others. Arms branch once again, usually on the sixth IIBr, occasionally on the fifth, except in the A ray where they either do not branch again or in one specimen branch on the eighth IIBR. Arms closely abutting throughout, Brr simple, noncuneiform. Pinnules short, stout. Sac unknown.

Column round, of alternately expanded columnals proximally, distally no expansion is visible. Stout cirri are apparently given off from nodals on the column not far below the cup.

Discussion.—*Dinotocrinus logani* is a simple, generalized form undoubtedly ancestral to the more advanced species known from Meramec and Chester rocks. It is closely related to both *Stinocrinus* (Kirk, 1941a, p. 84) and *Sarocrinus* (Kirk, 1942, p. 382) from which it differs in having only one IBr instead of two. Probably all three of these genera can be considered as primitive ancestors of the zeacrinitids.

Occurrence.—Lodgepole formation, Bridger Mountains, Montana.

Types.—Holotype, USNM No. 123158; paratypes, USNM Nos. 123155, 123156, 123157, 123159.

ZEACRINITIDAE Moore and Laudon, 1943
LINOCRINUS Kirk, 1938

The genus *Linocrinus* was established by Kirk (1938, p. 168) for crinoids that had been previously housed mainly in the genus *Zeacrinites*. The genus ranges throughout Mississippian rocks. Kinderhookian species had already developed the truncated

base with the IBB essentially confined to a concavity. The gaping suture between R and IBr_1 is only weakly developed in the Kinderhookian forms. Kirk (1938, p. 169) compares *Linocrinus* with *Decadocrinus* and suggests possible close relationships. We are of the opinion that *Decadocrinus* (Wachsmuth and Springer, 1879, p. 119) (Meek and Worthen, 1869, p. 145) was derived from a two-armed stock from far back in the Devonian and that it is far removed from the multi-armed *Linocrinus*. We consider that *Dinotocrinus* (Kirk, 1941b, p. 513), *Pachylocrinus* (Wachsmuth and Springer, 1879, p. 115), and *Abrotocrinus* (Miller and Gurley, 1890, p. 30) might all be considered as closely related ancestors of *Linocrinus*. *Dinotocrinus* would need only further bifurcation of the arms to be classed as *Linocrinus*. A reduction of the two IBrr of *Pachylocrinus* to one with other minor modifications would change *Pachylocrinus* to *Linocrinus*. Perhaps *Abrotocrinus* with its shallow cup, single IBr, gaping suture between R and IBr_1 and multiple branching arms is most closely related to *Linocrinus*. We do not infer that *Linocrinus* is a direct lineal descendant from any of these genera but that it came from some closely related stock.

LINOCRINUS WILSALLENSIS
Laudon and Severson, n. sp.
Plate 51, figure 28; plate 55, figure 15

Linocrinus wilsallensis is distinguished from all other known species of *Linocrinus* by the strange vertebrae-like flanges that are developed along the outer fringe of the upper articulation surfaces of the Brr in the lower arms. Tendencies for such flanges are developed in *L. nigelensis* Laudon, Parks, and Spreng (1952, p. 558), from the Banff formation of Alberta.

Cup shallow, base truncated, width at arm bases 10 mm., height 3 mm. IBB small, tips barely projecting from beneath column, confined to shallow basal concavity. BB curving around into the basal concavity, and directed only slightly outward on the lateral wall, making a conspicuous part of the lateral wall. RR wider than high, width 4 mm., height 2 mm., directed slightly outward. RA and X unknown.

IBr one except in anterior where there are five, first conspicuously large and marked entirely differently from succeeding Brr. IBr_1 suture with R only slightly gaping, articulating surface occupying full width of R. The Brr of lower arms above IBr_1 are constricted markedly in their lower extremities and flare in a conspicuous flange just beneath their upper articulating surfaces, a character which is gradually lost upwards in the arms. The upper arm Brr are simple, noncuneiform, typical of other species of the genus. A minimum of four bifurcations can be observed in the arms. The arms are long and slender, reaching approximately 30 mm. above the cup.

Pinnules are short and stubby but very few are preserved on the specimen.

Both sac and column are unknown.

Discussion.—*L. wilsallensis* is most closely related to the other two known Kinderhookian species. It differs from *L. nigelensis* from the Banff formation of Alberta in that the flange-like structures are not as well developed on the Banff species and the Banff species has distinctly more angular Brr. It differs from *L. compactus* (Laudon, 1933, p. 66) from the Gilmore City formation of Iowa in that the Gilmore City species has no tendencies for the flange-like structures.

Occurrence.—Approximately 25 feet above the base of the Lodgepole formation, Old Baldy Peak, Bridger Mountains, Montana.

Holotype.—USNM No. 123160.

SCYTALOCRINIDAE Moore and Laudon, 1943
BRIDGEROCRINUS, n. gen.

Genotype.—*Bridgerocrinus fairyensis* Severson and Laudon, n. gen. and n. sp.

The family Scytalocrinidae embraces a large number of inadunate crinoid genera with widely varying characters. The cup varies from primitive, steeply conical to shallowly bowl-shaped with the IBB not visible on the cup wall. All genera housed within the family are characterized by having only one bifurcation of the arms which may be on either the first or second IBr. The arms, simple to markedly cuneiform, may be smooth and round or sharply angular with a marked zig-zag appearance. The sac is long and slender in early forms to short and stubby in some of the later genera.

We are of the opinion that the primitive

scytalocrinids came directly from the Devonian ottawacrinids. Some Devonian scytalocrinids are characterized by steeply conical cups, long slender sacs, simple somewhat elongated Brr and long, slender, rounded arms. In only one Devonian species, *Decadocrinus multinodosus* Goldring (1923, p. 429), is the zig-zag arm structure that persists through Mississippian species observed. Several Devonian scytalocrinids developed the relatively shallow, bowl-shaped cup that characterizes many later forms.

If we were to choose a form from Devonian ottawacrinids most like the probable ancestor of the scytalocrinids, we would choose *Cradeocrinus elongatus* Goldring (1923, p. 348) from the Chemung beds of New York. In *Cradeocrinus* the RA is already pentagonal and in the normal position beneath Rt, the cup is steeply conical, the sac is long and slender, and the arms bifurcate only once. *Cradeocrinus* differs from the primitive scytalocrinids in that it does not develop normal pinnules and the bifurcation of the arms takes place on the third instead of the second IBr. Development of a primitive scytalocrinid from *Cradeocrinus* demands only the development of pinnules and fusion of two of the IBrr so that the arms bifurcate on IBr_2.

The new genus *Bridgerocrinus* is proposed to accommodate a number of species of primitive scytalocrinids in which the cup retains the primitive steeply conical shape, with the IBB making a conspicuous part of the lateral cup wall. The arms are long, slender, delicate; bifurcate once on IBr_2 and bear one long slender pinnule on each Br. The arms are rounded and the Brr are not cuneiform. The sac is composed of small hexagonal plates in parallel rows and is long and slender. RA is pentagonal and rests on PB and RPB, is laterally in contact with X and RPR, and is in contact above with Rt. The X plate lies on the truncated upper surface of PB. The column is round.

The genus *Scytalocrinus* would thus be limited to later species of scytalocrinids with a bowl-shaped cup, the IBB essentially not visible on the lateral cup wall, relatively stout, rounded arms and much shorter sacs in comparison to the arm length. The arms bifurcate on the first IBr instead of the second.

The range of *Bridgerocrinus* is from Upper Devonian through Mississippian, Osage.

BRIDGEROCRINUS FAIRYENSIS
Laudon and Severson, n. gen. and n. sp.
Plate 51, figures 6–8; plate 55, figure 5

A slender, delicate form. Cup steeply conical, crown relatively open, arms more than seven times the cup length.

Cup slightly higher than wide, height 3.8 mm., width 3.4 mm. at arm bases. IBB directed upward and slightly laterally, 1.1 mm. in height on holotype. BB higher than wide, height 1.9 mm., width 1.1 mm. in holotype. RR approximately equidimensional, width 1.2 mm. in holotype. RR facets occupy entire upper surface of R. RA pentagonal, resting on PB and RPB, in contact laterally with X and RPR, upper contact with Rt narrow, higher than wide. X on truncated upper surface of PB, contact narrow, higher than wide, approximately same size as RA, both smaller than R.

Arms long, slender, delicate, rounded, IBr_1 unusually long, suggesting probable origin by fusion of two Brr, length 2.8 mm. in holotype. IBr_2 shorter, axillary, 2.4 mm. in holotype, approximately equal in length with succeeding Brr. Succeeding arm Brr relatively long in comparison to width, averaging .6 mm. in the upper arms in length, width of upper arm Brr approximately .3 mm. Pinnules long, slender, delicate, directed abruptly upward at angles of between 10 and 30 degrees with main arms, arising from upper lateral surface of Br and arising on alternate sides of the arm.

Sac long, slender, reaching fully two-thirds of arm length, 19 mm. long on paratype, capped with terminal spine. Sac plates slightly irregular at mid-length, in parallel rows in upper portion.

Column apparently round, only a single columnal available for study.

Discussion.—Bridgerocrinus fairyensis is the most primitive scytalocrinid we have observed thus far in Mississippian rocks. Its slender delicate nature and high conical cup resembles the Devonian *Cradeocrinus*. The unusually long IBr_1, approximately twice the length of the succeeding Brr, suggests that *Bridgerocrinus* may have been derived from a form with three IBrr such as *Cradeocrinus*. *Bridgerocrinus* is easily separated

from all other later Mississippian scytalocrinids because of its unusually high conical cup and distinctive arm Brr.

Occurrence.—Lodgepole formation, Bridger Mountains, Montana; Sheep Mountain, Centennial Range, Montana.

Types.—Holotype, USNM No. 123139; paratypes, USNM Nos. 123138, 123140.

SCYTALOCRINIDAE Moore and Laudon, 1943

HYPSELOCRINUS Kirk, 1940

HYPSELOCRINUS MACCABEI
(Miller and Gurley)
Plate 51, figures 2–5

The genus *Hypselocrinus* was established by Kirk (1940, p. 325) for inadunate crinoids with moderately conical cups, RA and X in the normal position, a single IBr and long, slender, simple to cuneiform arms. The genus has a known range from Kinderhookian through Osagean rocks.

Hypselocrinus maccabei (Miller and Gurley) (1894, p. 34) is one of the most primitive representatives of the genus that we have observed thus far. The cup is moderately conical with the IBB showing on the lateral wall. The arms are long, slender, delicate, and the sac is slender. The arms branch on IBr_1 which is unusually long. All Brr are long and the pinnules are directed abruptly upward.

Hypselocrinus maccabei was first described from the Hampton formation at LeGrand, Iowa. It also occurs in the Gilmore City formation of Iowa and specimens closely resembling it are found in the Banff formation of Alberta.

Hypselocrinus was undoubtedly derived from *Bridgerocrinus*. It differs from *Bridgerocrinus* in that the cup expands a little more rapidly and the arms branch on IBr_1 instead of IBr_2.

Occurrence.—Lodgepole formation, Bridger Mountains, Montana.

Figured specimens.—USNM Nos. 123134, 123135, 123136, 123137.

RAMULOCRINUS Laudon, Parks, and Spreng

The genus *Ramulocrinus* was established by Laudon, Parks, and Spreng (1952, p. 557) for inadunate crinoids that had previously been included with the genus *Decadocrinus*. *Ramulocrinus* was set aside for forms having one bifurcation of the arms, a single IBr and the characteristic zig-zag appearance of the Brr found in *Decadocrinus*. *Ramulocrinus* is assumed to have evolved from *Decadocrinus* by fusion of the two IBrr into one. The cup of *Ramulocrinus* is bowl-shaped with the base truncated and the IBB showing only slightly on the lateral wall as in *Decadocrinus*. The truncate base separates *Ramulocrinus* from *Hypselocrinus* and the zig-zag arm structure separates *Ramulocrinus* from *Scytalocrinus*.

RAMULOCRINUS LIVINGSTONENSIS
Laudon and Severson, n. sp.
Plate 51, figures 16–19; plate 55, figures 8–9

Ramulocrinus livingstonensis is a primitive, slender, rather delicate, early form of the genus *Ramulocrinus*. The cup is still conical but definitely expanded beyond the high, steeply conical ancestors from which *Ramulocrinus* originated. The IBB are not yet confined to the basal concavity as they are on some of the later species.

Cup bowl-shaped, somewhat truncated, width 4.5 mm. at arm bases and 2.6 mm. high in holotype. IBB low, but definitely making a part of the lateral cup wall. BB much larger than IBB, directed slightly outward, approximately equidimensional. RR wider than high, 1.7 mm. in width and 1.2 mm. in height in holotype. Facets occupy entire upper surface of R, suture gaping, RA pentagonal, as large as X in normal position on PB and RPB, laterally in contact with X and RPR, and beneath Rt. X as large as PB and resting on truncated surface of PB, contact suture with PB narrow.

Crown open, with no indications of incurving at arm tips. IBr one, constricted at mid-length, essentially the same length as succeeding Brr. Arms branch only once. Brr long, abruptly cuneiform, with each succeeding brachial directed sharply at an angle to preceding Br which gives rise to the pronounced zig-zag pattern that characterizes the arms of both *Decadocrinus* and *Ramulocrinus*. Strong, robust ramule-like pinnules arise from each Br and are directed abruptly outward from the main arm. Anterior ray not observed.

Sac consists of normal, parallel rows of hexagonal plates at lower levels, upper part not observed.

Column round, in part of alternately expanded columnals, slender cirri arise a relatively short distance below the cup.

Remarks.—*Ramulocrinus livingstonensis* is easily separated from *R. nigelensis* Laudon, Parks, and Spreng (1952, p. 558) from the Banff formation of Alberta in that the RR of the Banff species flare outward abruptly at their junction with the RR. The arms of *R. nigelensis* have an unusual sharp sinuous ridge that accentuates the zig-zag appearance of the arms. *R. livingstonensis* compares most closely with *R. albertsi* (Miller and Gurley) (1896, p. 29) from the Chesteran rocks of Illinois. The cup of *R. albertsi* is decidedly more bowl-shaped and the IBB do not show on the lateral wall but the arms are closely similar. *R. halli* (Hall) (1861, p. 308), *R. granuliferus* (Miller and Gurley) (1888, p. 367), *R. repertus* (Miller and Gurley) (1888, p. 362), and *R. rudis* (Meek and Worthen) (1873, p. 412) all have much shorter Brr and less strong pinnules. *R. ulrichi* (Worthen) (1890, p. 87) is slender and delicate, and has arm Brr that are relatively long and markedly zig-zag in appearance. The pinnules are strong. The base of *R. ulrichi* is definitely more truncate and the IBB do not show on the lateral wall.

Occurrence.—Lodgepole formation, Bridger Mountains, Montana.

Types.—Holotype, USNM No. 123149; paratypes, USNM Nos. 123148, 123150, 123151.

Amphelecrinus Kirk, 1944

The genus *Amphelecrinus* was established by Kirk (1944, p. 190) for a group of inadunate crinoid species with moderately primitive, conical cups in which the IBB form a definite part of the cup wall, RA and X are in normal position, a single IBr is present, arms branch only once above first dichotom and relatively far above cup, and Brr are simple to slightly cuneiform. The suture between R and IBr is distinctly gaping. All of the species recognized by Kirk are from Upper Mississippian (Meramecian and Chesteran) rocks. Kirk states "*Amphelecrinus* seems to be more nearly related to *Phacelocrinus* than any other described genus" (1944, p. 191). Forms with a single bifurcation of the arms and high conical cups such as *Phacelocrinus* we believe to be evolved directly from Devonian scytalocrinids and see little if any relationships between *Phacelocrinus* and *Amphelecrinus*.

We believe that *Cosmetocrinus* (Kirk, 1941a, p. 86) was developed from an ancestor related to *Amphelecrinus* by addition of another bifurcation of the arms. The forms *Cosmetocrinus elegantatus* (Wachs-

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Explanation of Plate 51

All illustrations ×1 unless otherwise indicated.

Fig. *1*—*Amphelecrinus sacculatus* Laudon and Severson, n. sp., ×2, posterior view of holotype. (p. 522)

2–5—*Hypselocrinus maccabei* (Miller and Gurley), all ×2, *2*, *3*, *4*, *5*, lateral views. (p. 519)

6–8—*Bridgerocrinus fairyensis* Laudon and Severson, n. sp. *6*, posterior view of paratype; *7*, lateral view of holotype; *8*, lateral view of paratype. (p. 518)

9–12—*Cradeocrinus dendratus* Laudon and Severson, n. sp. *9*, lateral view of paratype; *10*, left posterior view of holotype; *11*, ×2, *12*, lateral views of paratypes. (p. 514)

13–14—*Cyathocrinites* sp. *13*, lateral view; *14*, left posterior view. (p. 513)

15—*Pelecocrinus* sp., ×½, right posterior view. (p. 515)

16–19—*Ramulocrinus livingstonensis* Laudon and Severson, n. sp. *16*, left posterior view of paratype; *17*, posterior view of holotype; *18*, right posterior view of paratype; *19*, ×2, left posterior view of paratype. (p. 519)

20–21—*Amphelecrinus madisonensis* Laudon and Severson, n. sp. *20*, posterior view of paratype; *21*, right anterior view of holotype. (p. 521)

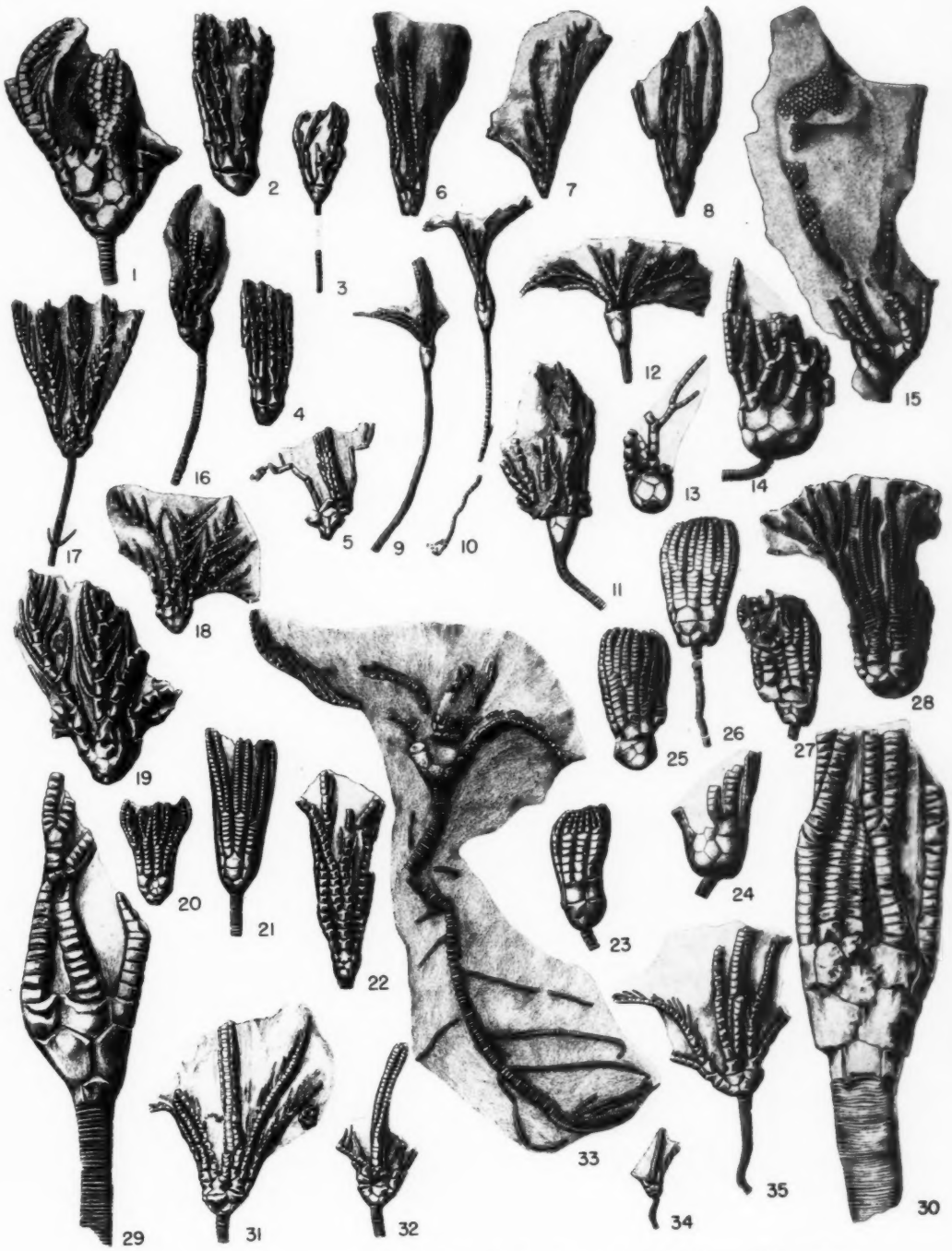
22—*Goniocrinus sculptilis* Miller and Gurley, ×2, lateral view. (p. 514)

23–27—*Dinotocrinus logani* Laudon and Severson, n. sp. *23*, ×3, lateral view of paratype; *24*, ×2, posterior view of a paratype; *25*, ×2, right anterior view of a paratype; *26*, ×2, left posterior view of holotype; *27*, ×2, lateral view of paratype. (p. 516)

28—*Linocrinus wilsallensis* Laudon and Severson, n. sp., left anterior view of holotype. (p. 517)

29–30—*Culmicrinus jeffersonensis* Laudon and Severson, n. sp. *29*, lateral view of paratype; *30*, posterior view of holotype. (p. 515)

31–35—*Holcocrinus longicirrifer* (Wachsmuth and Springer). *31*, anterior view; *32*, lateral view; *33*, view of specimen showing cirri; *34*, posterior view; *35*, lateral view. (p. 522)



Laudon and Severson, New Mississippian crinoids from Montana

Laudon and Severson, New Mississippian crinoids from Montana

muth and Springer) (1890, p. 195), *C. meeki* (Kirk) (1941a, p. 88), and *C. richfieldensis* (Worthen) (1883, p. 285) should be referred to *Amphelecrinus*.

The ancestors of Upper Mississippian *Amphelecrinus* seem to be found throughout Kinderhookian and Osagean rocks. The earlier Mississippian species to which we refer in general are characterized by much less cuneiform Brr and the R-IBr suture is usually not gaping. In all other characters they are essentially identical. It may eventually seem desirable to propose a new generic name for these slightly more primitive early Mississippian species. We are provisionally referring them to *Amphelecrinus* at the present time, thereby extending the range of the genus down through the entire Lower Mississippian.

Amphelecrinus madisonensis
Laudon and Severson, n. sp.
Plate 51, figures 20–21; plate 55, figures 10–11

Cup conical, moderately expanded, height 4 mm., width at arm bases 6.5 mm. in holotype.

IBB moderately large, erect, forming a definite part of lateral cup wall, two-thirds height of BB. BB smaller than RR, equidimensional. RR wider than high, width 3.5 mm., height 2.2 mm. RR suture not gaping, facet occupies full width of R. RA pentagonal, in normal position on PB and RPB, laterally in contact with X and RPR, beneath Rt. X smaller than RA, on truncated PB. IBr one, except in anterior ray where there are seven, not constricted at mid-length, conspicuously larger than succeeding Brr. IIBrr from six to eight. Arms branching a second time at about mid-length, not branching beyond second bifurcation. Brr simple, exhibiting no tendency to become cuneiform. Length of arms in holotype 21 mm. Pinnules short, closely packed.

Sac not observed.

Column round, columnals alternately expanded.

Discussion.—*Amphelecrinus madisonensis* can be separated from all of the Upper Mississippian species of *Amphelecrinus* on the basis of its noncuneiform arms. *A. richfieldensis* (Worthen) (1883, p. 285) from the Kinderhookian of Ohio is most closely similar to *A. madisonensis*. The Ohio species is considerably more delicate and the arms are slightly cuneiform. *A. nanus* (Meek and Worthen) (1873, p. 423) from the lower Burlington beds also has more delicate arms and they branch the second time on the sixth IBrr. *A. elegantulus* (Wachsmuth and Springer) (1890, p. 195) differs in that the arms flare beyond their mid-length and then recurve sharply near the tips. It is also a considerably more delicate species.

Occurrence.—Lower part of the Lodgepole formation approximately 15 feet above the base, Old Baldy Peak, Bridger Mountains, Montana.

Explanation of Plate 52

All illustrations ×1 unless otherwise indicated.

Figs. *1–2*—*Periechocrinites* sp. *1*, lateral view of damaged specimen; *2*, lateral view. (p. 527)

3–5—*Rhodocrinites cirrusi* Laudon, Parks, and Spreng. *3*, ×2; *4*, ×4; *5*, ×2½, lateral views. (p. 524)

6–8—*Rhodocrinites priminodosus* Laudon and Severson, n. sp. *6*, right anterior view of holotype *7*, left anterior view of holotype; *8*, lateral view of paratype. (p. 525)

9–12—*Rhodocrinites macrotumidus* Laudon and Severson, n. sp. *9*, ×3, lateral view of paratype; *10*, ×3, lateral view of holotype; *11*, ×2, lateral view of paratype; *12*, ×2, lateral view of paratype. (p. 524)

13–19—*Rhodocrinites douglassi* (Miller and Gurley). *13*, *14*, *15*, lateral views; *16*, ventral view showing position of anal opening; *17*, right posterior view showing constriction at arm level and flat tegmen; *18*, lateral view; *19*, right anterior view. (p. 524)

20–22—*Cribanocrinus watersianus* (Wachsmuth and Springer). *20*, ×2, lateral view of a specimen referred tentatively to *C. watersianus* although it shows faint tendencies for stellate markings; *21*, lateral view; *22*, basal view. (p. 526)

23–27—*Batocrinus gallatinensis* Laudon and Severson, n. sp. *23*, anterior view; *24*, posterior view of paratypes; *25*, ×2, lateral view of a specimen showing vermiculate plate markings; *26* ×2, lateral view of a paratype showing anal tube; *27*, lateral view of holotype. (p. 526)

Types.—Holotype, USNM No. 123153; paratype, USNM No. 123152.

AMPHELECRINUS SACCULATUS
Laudon and Severson, n. sp.
Plate 51, figure 1; plate 55, figure 7

This species is represented by a single somewhat damaged specimen in our collections. It is considerably shorter and more stout than any of the other known species referred to *Amphelecrinus*. The cup is wider and more abruptly expanding than that of *A. madisonensis*.

Cup conical, rapidly expanding, 3.2 mm. in height, 6 mm. in width at arm bases, Crown open, arms flaring outward and recurving at tips.

IBB small, directed abruptly laterally and slightly upward, only partially visible on lateral wall. BB erect, directed slightly laterally, equidimensional, approximately 2 mm. RR wider than high, width 2.2 mm., height 1.7 mm., facets occupy entire upper surface of RR, suture gaping. RA pentagonal, in normal position on PB and RPB, laterally in contact with X and RPR, beneath Rt, as large as X. Anal resting on truncated PB, followed by three rows of hexagonal plates that make one side of a small rounded, posteriorward projecting tube. The sac expands abruptly at about the mid-length, the plates become stellate with the usual pores at the plate corners, in the upper sac every other vertical row of plates is raised into a conspicuous ridge, a terminal spine caps the sac.

The arms are short and stout. IBr one, somewhat longer than succeeding Brr, not constricted at mid-length. Brr slightly but not conspicuously cuneiform, the second bifurcation of arms is on $IIBr_6$. In the only arm available for study no additional branching is noted. Anterior arm not observed. Pinnules stout, directed slightly laterally and upward.

Column round.

Discussion.—*Amphelecrinus sacculatus* is differentiated from all other known species because of its short, stout, stubby character. The rapidly expanding cup represents an advanced stage of evolution for Kinderhookian species of *Amphelecrinus*.

Occurrence.—Lodgepole formation, Bridger Mountains, Montana.

Holotype.—USNM No. 123133.

ERISOCRINIDAE S. A. Miller, 1889
HOLCOCRINUS Kirk, 1945
HOLCOCRINUS LONGICIRRIFER
(Wachsmuth and Springer)
Plate 51, figures 31–35; plate 55, figure 2

The occurrence of four specimens of *H. longicirrifer* (Wachsmuth and Springer) (1890, p. 251), all of which show the long slender anal sac, is unusual. In addition to the four specimens showing the sac, one fragmentary specimen has been found which shows the long cirri on the column for which the species was named.

Holcocrinus is assumed to have evolved from a progressive stock with a broadly expanded bowl-shaped cup with two anals within the cup. Since the general trend observed in most crinoids has been toward eventual elimination of all anal plates from the cup, thus establishing perfect pentamerous symmetry, we assume that *Holcocrinus* has been evolved by elimination upward of one of the anal plates. Since RA normally occupies the lower position in the cup we assume that X has been eliminated upward and that the so-called X plate in *Holcocrinus* is actually RA.

A search for the potential ancestors of *Holcocrinus* and its younger relative *Graphiocrinus* among Devonian forms yields abundant evidence among the Devonian decadocrinids. In such forms as *Decadocrinus multinodosus* Goldring (1923, p. 429) the cup is already broadly bowl-shaped with the IBB essentially not visible on the lateral cup wall, the arms branch only once and are markedly cuneiform. *D. multinodosus* has an unusually large RA shifted to a position directly beneath the center of the posterior interradius, X has been shifted far to the left and is in contact with PB only at one point, a series of strong, median, hexagonal plates follow upward onto the center of the sac above RA.

To develop *Holcocrinus* from some close relative of *D. multinodosus*, it would only be necessary to shift X a fraction of a millimeter farther to the left so that the contact between PB and X are broken, reduce the IBr to one from the two of *Decadocrinus*, which is a normal progressive development among inadunate crinoids, and develop

some of the minor characteristics such as the cirri on the column. The sac of Devonian decadocrinids is remarkably similar to the long slender sac of *Holcocrinus*.

Occurrence.—Lodgepole formation, Bridger Mountains, Montana.

Figured specimens.—USNM Nos. 123163, 123164, 123165, 123166, 123167.

TAXOCRINIDAE Angelin, 1878
EUTAXOCRINUS Springer, 1906
EUTAXOCRINUS MONTANENSIS Springer
Plate 54, figures 18–20

Several specimens of *E. montanensis* are present in our collections. Since the only known specimen, figured by Springer (1920, p. 372), showed only the posterior side, we are figuring two specimens to show the character of the IBrr between the other rays.

Occurrence.—Lodgepole formation, Bridger Mountains, Montana.

Figured specimens.—USNM Nos. 123220, 123221, 123222.

RHODOCRINITIDAE Bassler, 1938
RHODOCRINITES Miller, 1821

Space is not available within the limits of this paper to present evidence concerning the details of evolution among the species of *Rhodocrinites*. It will be necessary however to present some of the established evolutionary trends before any discussion of species can be attempted.

The essential dicyclic structure and general cup arrangement of the Rhodocrinitidae has its origin far back in Ordovician diabolicrinids. Very little modification of this early structure is necessary to produce *Rhodocrinites*. Primitive rhodocrinitids, judging from their diabolocrinid ancestors, should possess, rounded, ball-shaped cups, IBB small and perhaps confined to a basal concavity, primitive ray ridges, numerous IBrr broadly connected to the tegmen, a constricted tegminal area made essentially of many small plates, with an anal opening directly through the tegmen. Any departure from these primitive characters can be considered as indicating advanced evolutionary stages.

Since the fundamental arrangement of plates in the cup, and even the general cup shape itself is remarkably similar in all species of *Rhodocrinites*, it has been necessary to seek elsewhere for characters to use in differentiating the various stages of evolution within the genus. We have found that the general nature of the tegmen is the most valid single character to use in evaluating stage of evolution within the genus.

The fundamental rhodocrinitid tegmen was greatly restricted in size in comparison to the total width of the cup, consisted of many unusually small, relatively smooth, non-nodose plates, and the interradial tegminal areas were depressed.

During the Mississippian history of *Rhodocrinites* the number of plates in the tegmen was gradually reduced and their over-all size was gradually increased. In some species the width of the tegmen was gradually increased until in some of the more highly specialized species it equals or slightly exceeds the total width of the cup. The interradial depressions are gradually eliminated and in many specialized species the tegmen becomes essentially flat. Tegmen plates gradually become rugose and nodose. The position of the anal opening remains fundamentally in the same slightly eccentric position but the plates that immediately surround the anal opening vary greatly with the different species.

The arms were directed upward and slightly outward in the primitive species and in later specialized forms were directed abruptly outward from the cup. In immature and primitive specimens the arms were uniserial and bifurcated only once. A second bifurcation appeared first high up on the arms and gradually shifted downward toward the cup in the later more specialized species. Further bifurcation of the arms developed eight arms to the ray in the most advanced types. In immature specimens of advanced species the arms are uniserial and long in the infantile stages of development, become gradually cuneiform as age increases, beginning at the arm tips, and become closely packed, fully biserial in adult stages of development. Fully adult species with the arms exhibiting various stages of this evolution can be found in various parts of the Mississippian section. For example, fully adult specimens of *R. brewsteri* Laudon, Parks, and Spreng (1952, p. 561) have arms that reach only the cuneiform stage of development. *R. cirrusi* Laudon, Parks, and Spreng (1952, p. 563) has arms that have

not progressed beyond the uniserial stage and the second bifurcation takes place high in the arms. Thus it can be seen that the position of the second bifurcation of the arms becomes important in allocation of a correct position of a species to the established trends of evolution.

Rhodocrinites douglassi
(Miller and Gurley)
Plate 52, figures 13–19

R. douglassi (Miller and Gurley) (1897, p. 39) was described from a single somewhat crushed specimen. It is the most abundant species of *Rhodocrinites* in our collections from Montana. As in the Gilmore City formation of Iowa (Laudon, 1933, pp. 39–47), *Rhodocrinites douglassi* exists in several varieties in the Lodgepole formation. Because of the seemingly almost complete intergradation of these variants we have decided not to attempt to assign them to specific categories. With thousands of specimens now available from Gilmore City, almost complete evolutionary series can be established.

R. douglassi represents a relatively advanced form of the genus *Rhodocrinites*. The cup is rounded, globose, plates markedly stellate, arms laterally directed, the tegmen approaches the full cup width, tends to be pentagonal in outline, is flat on top, has large rugose to spinose plates, and in general tends to slightly overhang the somewhat constricted area at the level of the arm openings.

We have figured several of the variants for their stratigraphic value.

Occurrence.—Abundant in several zones within the Lodgepole formation of Montana, We have recovered specimens from the Bridger Mountains, the Little Belt Mountains, the Tobacco Root Mountains, and the Big Snowy range. It has seemed remarkable to us that none of the specimens from the Banff formation in Alberta have progressed as far as the *R. douglassi* stage in evolution.

Figured specimens.—USNM Nos. 123179, 123180, 123181, 123182.

Rhodocrinites cirrusi
Laudon, Parks, and Spreng
Plate 52, figures 3–5

R. cirrusi Laudon, Parks, and Spreng (1952, p. 563) is the most primitive species of *Rhodocrinites* known to us at present. Several variants have been classed together under the specific name *R. cirrusi*. When additional materials are available it may seem desirable to subdivide the species.

As defined at present we have included all specimens in which the arms are in the primitive uniserial condition and in which the second bifurcation does not take place until relatively high in the arms. Since all species of *Rhodocrinites* have uniserial arms in the immature specimens, the position of the second bifurcation of the arms becomes important in classification. It has been assumed that the original ancestor of *Rhodocrinites* was uniserial and had only one bifurcation of the arms. One specimen (plate 52, fig. 5) from the Lodgepole formation of Montana has two unbranched arms in one of the rays. One of the rays however branches on the twelfth Br. The second bifurcation of the arms of the holotype from the Banff formation in Alberta took place on the eighth Br which can be interpreted as somewhat advanced over at least some of the Lodgepole specimens. The second bifurcation of the arms is variable in the Lodgepole specimens taking place on from ninth to twelfth Brr.

Occurrence.—Lodgepole formation, Bridger Mountains, Montana.

Figured specimens.—USNM Nos. 123170, 123171, 123172.

Rhodocrinites macrotumidus
Laudon and Severson, n. sp.
Plate 52, figures 9–12; plate 55, figures 17–18

R. macrotumidus is a small species, with an expanded globular cup, deeply stellate plates, restricted tegminal area with unusually large nodose tegmen plates. The arms bifurcate once in most rays and twice in some, the second bifurcation in the normal advanced position low in the arm structure. *R. macrotumidus* is allocated specific recognition on the basis of unusually few large nodose tegmen plates.

Cup dicyclic, rounded, restricted at arm bases, height to arm bases 6 mm., maximum width 7 mm. on holotype.

Base invaginated, IBB confined to basal concavity, RR in contact, curving around base to make an appreciable part of lateral

cup wall, truncated to support primary iBr, X identical in appearance to iBr. RR separated all around, heptagonal, equidimensional, maximum width of cup at top of RR. IBrr two, first quadrangular, or pentagonal, slightly wider than high, second axillary, pentagonal or hexagonal. IIBr one, notched at top for ambulacral opening. The two ambulacral openings for each ray separated by strong, nodose, laterally projecting plate in contact beneath with IIBrr, notched for ambulacral opening laterally and laterally in contact above ambulacral openings with large, nodose, laterally projecting plate that terminates the IBrr series and makes the rim of the tegmen. Primary iBr large, pentagonal, equidimensional, resting on truncated B, followed by 2, 2, 1, 1 plates within the IBr series. The large terminal IBr is notched at its base for the ambulacral opening. X area not differentiated by extra plates.

Tegmen consists of unusually nodose, large plates except for anal area.

Arms bifurcate once normally, but in some rays twice, bifurcation close to cup, arms biserial above bifurcation. Pinnules short. Arms short and incurved at top.

Column round, typical of *Rhodocrinites*, of alternately expanded columnals.

Discussion.—The cup of *R. macrotumidus* is similar to that of *R. douglassi*. Without the tegmen it would be difficult to distinguish the species. The highly nodose tegmen of very few plates represents a very advanced stage in rhodocrinitid evolution. The only other species we know with as nodose a tegmen is *R. barrisi* (Hall) (1861, p. 9) from the Burlington limestone. The equally strange spinose cup of *R. barrisi* immediately separates it from *R. macrotumidus*.

Occurrence.—Lodgepole formation, Bridger Mountains, Montana.

Types.—Holotype, USNM No. 123176; paratypes, USNM Nos. 123175, 123177, 123178.

Rhodocrinites priminodosus
Laudon and Severson, n. sp.
Plate 52, figures 6–8; plate 55, figure 16

This species of *Rhodocrinites* is recognized because of its exceedingly nodose plate markings both on the cup and tegmen. The cup is rapidly expanding, widest at arm bases, not rounded, globose; the tegmen is primitive with numerous small plates, all unusually nodose.

Cup conical, somewhat elongated as in *R. kirbyi* (Wachsmuth and Springer) (1890, p. 180), width 16 mm. at arm bases, height 7 mm., on holotype. IBB small, confined to basal concavity. BB curve around base to make conspicuous part of lateral cup wall, directed slightly laterally, truncated at contact with iBr. RR separated all around, wider than high, width 3.4 mm., height 3.2 mm., in contact laterally with iBr. IBrr two, first quadrangular, approximately half width of RR, second pentagonal, axillary. IIBrr two, wider than IBrr, the second separated by a small iIIBr. Primary IBr pentagonal, resting on truncated B, laterally in contact with R and supporting two plates in the second cycle in three iBrr areas and three plates in the second cycle in one iBr area. The anal interradius is not available for observation. Interbrachial areas long, plates small in upper portions, in primitive stage of evolution. Larger, fewer iBrr plates is the normal trend in evolution in rhodocrinitids. A conspicuous ray ridge that comes to an acuminate peak on each plate runs up the middle of each ray. The ray ridge bifurcates on the RR plates passing laterally downward onto the middle of the BB plates. A conspicuous ridge also runs laterally across the BB plates making a conspicuous pentagonal rim around the base. iBrr plates are not stellate but each plate is marked with a sharp central spine-like node.

Arms directed upward and only slightly laterally, incompletely known and fragmentary on both specimens in our collections. The acuminate ray ridge runs directly into the arms so that it is difficult to determine exactly where the free arms begin. IIIBrr one or two, strangely truncated so that in at least one case IVBr rest on IIBr. IVBrr one, followed after one VBr by biserial arms. This rapid bifurcation of arms is a distinctly advanced character for rhodocrinitids and the establishment of biserial character immediately above the last bifurcation is also advanced.

Tegmen large, broadly expanded, conical, not flat, not sharply pentagonal, terminating in an eccentric, relatively high anal

pyramid. The tegmen is made of unusually small plates and is definitely primitive like the tegmen of *R. kirbyi*. Each tegmen plate is adorned with a sharply pointed spine. These spines become sharper immediately surrounding the anal opening.

Discussion.—*R. priminodosus* can be distinguished from all other species by its spinose character alone. Its expanding cup, widest at the arm bases, with numerous iBrr and small tegmen plates compares most closely with *R. kirbyi* (Wachsmuth and Springer) (1890, p. 180) or with *R. octadactylus* (Laudon and Beane) (1937, p. 242).

Occurrence.—Lodgepole formation, holotype from Big Snowy Mountains, Half Moon Pass, Montana; paratype from Bridger Mountains, Montana.

Types.—Holotype, USNM No. 123173; paratype, USNM No. 123174.

Cribanocrinus Kirk, 1944

Cribanocrinus watersianus (Wachsmuth and Springer)

Plate 52, figures 20–22

Cribanocrinus watersianus (Wachsmuth and Springer) (1890, p. 184) occurs in close association with *C. wortheni* (Hall) (1856, p. 556) in both the Gilmore City formation and the Hampton formation at LeGrand, Iowa, in the Mississippi Valley area. *C. watersianus* differs from *C. wortheni* only in that the former has four arms to the ray instead of six.

C. watersianus is figured here for its stratigraphic value only. One of our specimens shows three arms on one side of one ray suggesting that it may lie somewhere between *C. watersianus* and *C. wortheni* in the scale of evolution.

Occurrence.—Lodgepole formation, Bridger Mountains, Montana.

Figured specimens.—USNM Nos. 123185, 123186, 123187.

Batocrinidae Wachsmuth and Springer, 1897

The fundamental batocrinid cup structure was present in Silurian *Desmidocrinus* and well defined in the first aorocrinids in the Devonian. The Batocrinidae are differentiated from the Desmidocrinidae solely on the basis of anal tube versus direct opening of anal through the tegmen. No batocrinids are known from rocks older than Mississippian. *Batocrinus* occurs sparingly in Kinderhookian rocks and becomes prolifically abundant in Osagean rocks and then disappears entirely at the end of the Osage.

Kinderhookian batocrinids are generalized, differing from *Aorocrinus* only in the possession of an anal tube. They apparently were derived from a species of *Aorocrinus* with four arms to the ray because none of the primitive batocrinids have fewer than this number of arms. In *Aorocrinus* the arms were grouped with IBrr broadly connected with iAmbAmb on the tegmen. By definition the IBrr in *Batocrinus* are bridged over by an arch of Brr and separated from tegmen plates.

Batocrinus gallatinensis Laudon and Severson, n. sp.

Plate 55, figures 19–21; plate 52, figures 23–27

In such primitive forms as *B. gallatinensis* IBrr plates separate the rays in some rays and are bridged over by Brr plates isolating IBrr plates in the cup in other rays. Such an individual would lie somewhere in the scale of evolution between *Batocrinus* in which the arms are not grouped and *Uperocrinus* in which they are grouped. This species is referred provisionally to *Batocrinus* although we recognize that it has not reached the full *Batocrinus* stage of evolution in all characters.

Cup conical to slightly rounded, widest at arm bases, width 11 mm., height 8 mm. in holotype. Crown expanding with a slight incurving at the arm tips.

BB three, equal, expanded into slight rim, forming only a low minor part of the lateral cup wall. RR five, separated on posterior by X, hexagonal, width 3.8 mm., height 2.9 mm., on holotype. IBrr two, first quadrangular, width 2.4 mm., height 1 mm., in holotype, second pentagonal, axillary slightly wider than IBr_1, IIBrr two, except in anterior where rays do not bifurcate again. IIIBrr one, followed by free arms. Primary iBr large in contact with R, IBr_1, IBr_2, and $IIBr_1$, followed by one or two very small plates. On holotype a single IBr separates arms on at least two of the rays. X heptagonal, larger than R, followed by

three plates in next range, area much more widely differentiated than iBrr area, arms on posterior separated by plates of X series. Plates smooth, except for small tubercles and a faint reticulation present on one specimen.

Tegmen conical, grading upward into long stout anal tube that reaches considerably beyond arm tips, tegmen plates slightly nodose.

Arms four to the ray except on anterior where there are only two, biserial almost immediately above cup. Pinnules long, slender.

Column round, of alternately expanded columnals.

Discussion.—*B. gallatinensis* is most closely related to *B. macbridei* Wachsmuth and Springer (1890, p. 172) and is separated from it only on the basis of the fact that all iBrr are isolated in the cup by a bridge of Brr in *B. macbridei* while the more primitive *B. gallatinensis* has Brr in contact with tegmen plates in part.

Occurrence.—Lodgepole formation, Bridger range, Montana. Also present in Big Snowy Mountains, Montana.

Types.—Holotype, USNM No. 123192; paratype, USNM Nos. 123188, 123189, 123190, 123191.

Aorocrinus douglassi (Miller and Gurley)
Plate 53, figures 11–12

This species was described as *Batocrinus douglassi* by Miller and Gurley (1897, p. 29) from specimens collected from the Madison limestone in Bridger Canyon, north of Bozeman, Montana. The presence or absence of an anal tube could not be determined from the holotype nor can it be determined from the two specimens in our collections. However, since the arms are definitely grouped and because it is very similar to *A. radiatus* (Wachsmuth and Springer) (1890, p. 176) from the Hampton formation at LeGrand, Iowa, we are referring it to *Aorocrinus*.

None of the other species of *Aorocrinus* nor any of its immediate ancestors, nor any of its close relatives in the Batocrinidae are stellate. We look with question on assignment of this species to *Aorocrinus* and suggest that it may have been derived directly from *Athabascacrinus* Laudon, Parks, and Spreng (1952, p. 566). *Athabascacrinus*, a periechocrinitid, derived from Devonian *Gennaeocrinus*, is stellate, has identical plate structure, and comes from correlative beds (Banff formation, Alberta). *Athabascacrinus*, however, has arms that branch high above the cup much as in *Megistocrinus*. The very broadly expanding cup and closely packed biserial arms of *A. douglassi* also suggest relationship to *Athabascacrinus* rather than to *Aorocrinus*.

Because the original description by Miller and Gurley was rather incomplete, we present the following analysis.

Cup rapidly expanding, three times as wide as high. Crown open. BB three, equal, not forming a conspicuous rim as in *Aorocrinus*, directed essentially laterally. RR five, separated by X, wider than high, IBr two, first quadrangular, second pentagonal, axillary. IIBrr two, except when arm does not branch again. IIIBr one, followed by free arms. Primary ibr large, in contact with R, IBr_1, IBr_2, and $IIBr_1$, followed by two plates. A single small plate separates the iBrr and makes contact with tegmen plates. X heptagonal, higher than wide, followed by 3, 3, 2 in succeeding ranges. Brr widely separated on posterior.

Arms four to the ray normally, with three to the ray as a variant. On one specimen there are three on the anterior ray, three on the left anterior ray and four on each of the other three. Arms biserial almost immediately above cup, of unusually close packed biserial Brr. Pinnules long, slender. Column unknown.

Discussion.—*A. douglassi* differs from *A. radiatus*, its only close relative, in that *A. radiatus* has two arms to the ray.

Occurrence.—Lodgepole formation, Old Baldy Peak, Bridger range, Montana.

Figured specimens.—USNM Nos. 123201, 123202.

Periechocrinitidae Moore and Laudon, 1943

Periechocrinites Austin and Austin, 1842

Periechocrinites sp.
Plate 52, figures 1–2

It is not within the scope of this paper to enter into a discussion of the nomenclatural problems surrounding the genus *Periecho-*

crinites and the family Periechocrinitidae. Since the original description of *Periechocrinites* is based on fragmentary, essentially indeterminate remains, use of the name at all is open to question. Over the years the name *Periechocrinites* has been used for a very definite, well-defined group of crinoids. The specimens presented here from the Lodgepole formation of Montana are related to that group. Hence, pending complete revision of the group we are referring our specimens to *Periechocrinites*.

The Lodgepole specimens are closely related to *P. whitei* (Hall) (1861, p. 271) from the Burlington limestone of the Mississippi Valley area. They are figured here for stratigraphic value.

Occurrence.—Lodgepole formation, Old Baldy Peak, Bridger Mountains, Montana.

Figured specimens.—USNM Nos. 123168, 123169.

ACTINOCRINITIDAE Bassler, 1938
ACTINOCRINITES Miller, 1821
ACTINOCRINITES sp.
Plate 53, figure 7

The genus *Actinocrinites* is represented by a single badly crushed specimen in our collections. The cup itself is badly mashed and missing in part, the tegmen is fairly complete, but the anal tube is missing. There is no question of assignment of the specimen to *Actinocrinites*.

The cup is apparently rapidly expanding, the outline at the arm bases is deeply pentalobate as in some of the more advanced species of *Actinocrinites*. The arm openings are laterally directed and not visible from above. The anal is followed by two plates as is usual. Tegmen plates are moderately large.

The tegmen with its markedly pentalobate outline, deeply indented iBrr and iAmbAmb areas suggests that it may have been ancestral to such forms as *A. multiradiatus* (Shumard) (1857, p. 75) and *A. verrucosus* (Hall) (1858, p. 578) from the Burlington formation of the Mississippi Valley area.

The specimen is figured for stratigraphic value.

Occurrence.—Lowermost limestone beds, Lodgepole formation, Old Baldy Peak, Bridger range, Montana.

Figured specimen.—USNM No. 123199.

ABACTINOCRINUS Laudon and Severson, n. gen.

Genotype.—*Abactinocrinus rossei* Laudon and Severson, n. gen. and n. sp.

This new genus is being proposed on the basis of a single specimen. Under normal circumstances we should prefer to search for additional materials but due to the unusual characters exhibited by this single specimen, we have decided to propose both generic and specific names. We believe that this species will aid considerably in the understanding of the evolution of the Actinocrinitidae.

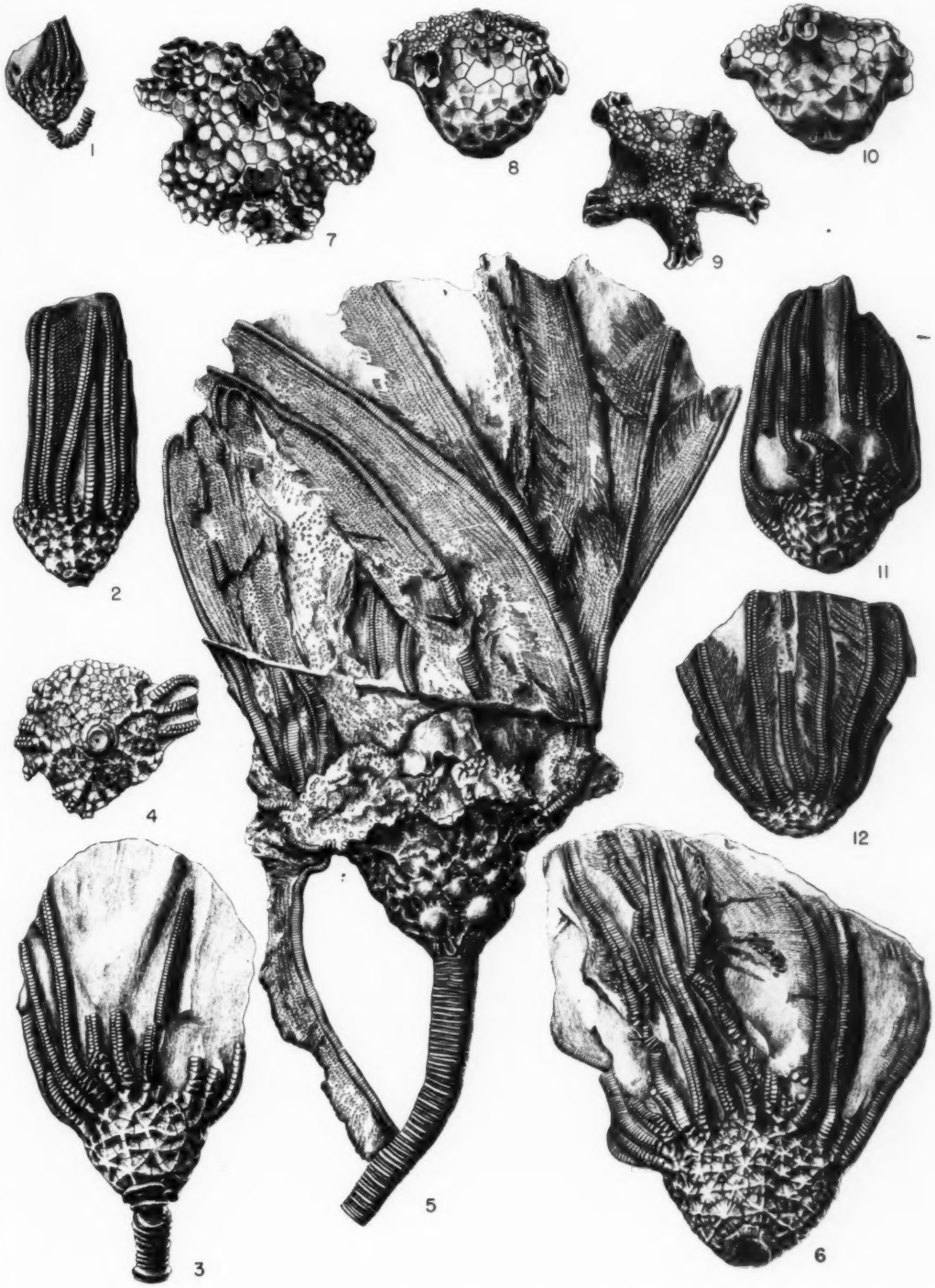
The cup of *Abactinocrinus* resembles the cup of *Steganocrinus pentagonus* Hall (1858, p. 577). The cup expands rapidly and flares at the top of IBr_1. The cup structure is typical for *Actinocrinites*, BB three, RR five plus X, X followed by three in next range, IBr_5 hexagonal, IBr_2 axillary, primary IBr large.

The cup flares into tube-like projections similar to the projections that characterize some of the more advanced species of *Actinocrinites*. The iBrr and iAmbAmb areas are constricted at the level of the

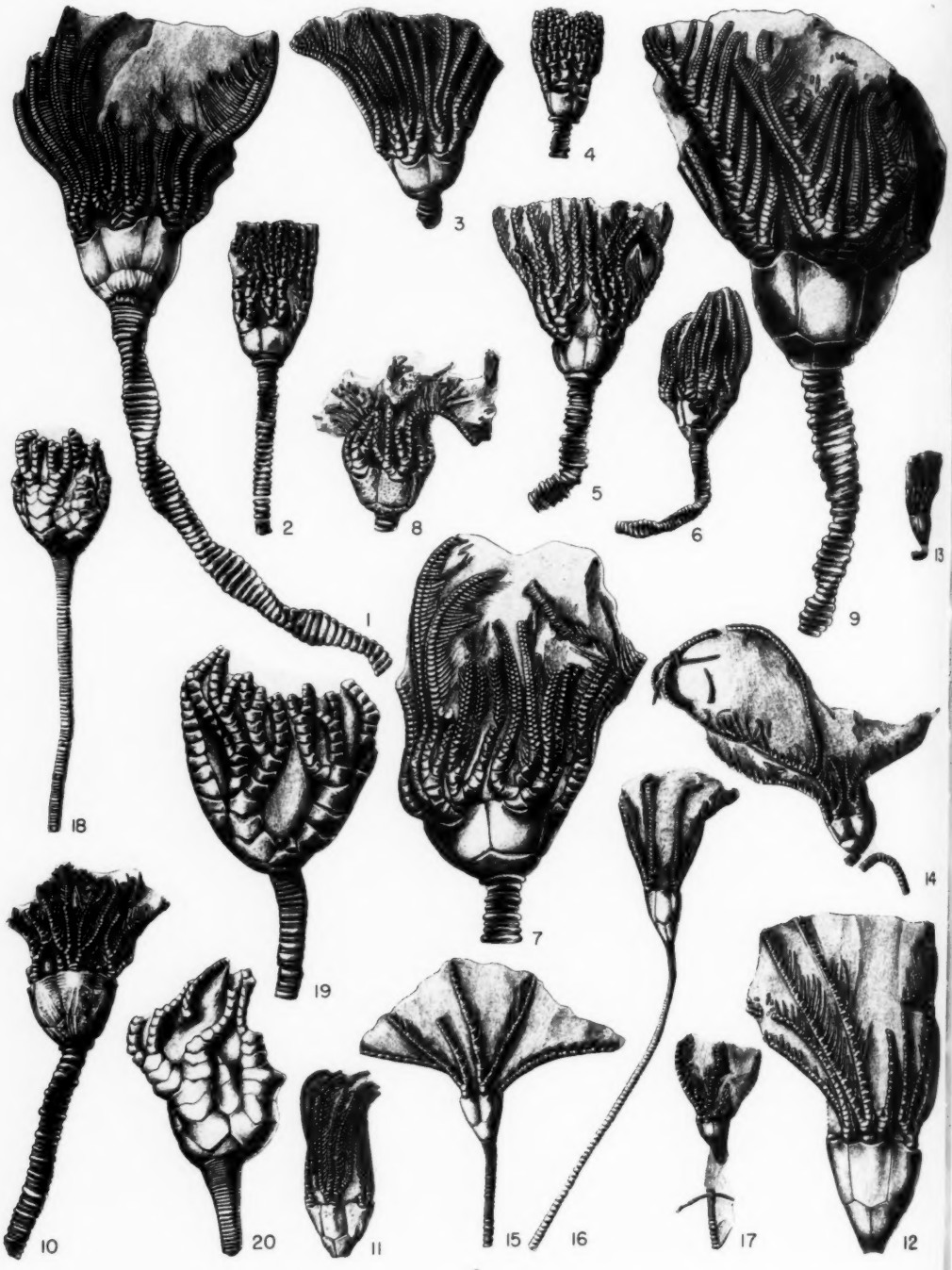
EXPLANATION OF PLATE 53

All illustrations ×1 unless otherwise indicated.

FIGS. *1–3*—*Cactocrinus arnoldi* Wachsmuth and Springer. *1*, lateral view of small specimen; *2*, anterior view; *3*, ×1½, lateral view. (p. 530)
4—*Cactocrinus ornatissimus* Wachsmuth and Springer, basal view of an irregular specimen in which the X plate is followed by four plates in the second range. (p. 530)
5—*Cactocrinus magnidactylus* Laudon and Severson, n. sp., ×¾, lateral view of holotype. (p. 531)
6—*Cactocrinus nodobrachiatus* Wachsmuth and Springer, lateral view. (p. 530)
7—*Actinocrinites* sp. ventral view. (p. 528)
8–10—*Abactinocrinus rossei* Laudon and Severson, n. sp. *8*, posterior view, *9*, ventral view; *10*, right anterior view of holotype. (p. 529)
11–12—*Aorocrinus douglassi* (Miller and Gurley). *11*, right posterior view; *12*, left anterior view. (p. 527)



Laudon and Severson, New Mississippian crinoids from Montana



Laudon and Severson, New Mississippian crinoids from Montana

arms giving a markedly pentalobate appearance in the cross section view at the arm level. Two ambulacral openings from each ray are directly laterally and slightly upward, making them distinctly visible from a ventral view. The iamb areas are depressed immediately above the cup level and are made up of small plates. The ambulacral areas are marked by strong lobe-like projections that are distinctly set aside from the depressed iamb areas. Plates of the whole tegmen are usually small and primitive in stage of evolution. Ambulacral plates are adorned with slender central spines.

The anus opens directly through the tegmen from a distinctly eccentric position. The anal opening is surrounded by minute, spinose plates.

The Actinocrinitidae are assumed to have been evolved directly from the Periechocrinitidae. The normal periechocrinitid cup needs only the upward displacement of one of the anal plates in the second range, thus having the X plate followed by two instead of three plates, to have the essentials of the primitive actinocrinitid cup. Devonian *Gennaeocrinus*, although not in the direct line of ancestry, may have been derived from the same unknown ancestral stock that gave rise to the actinocrinitids. Although the anus opens directly through the tegmen in *Gennaeocrinus*, the comparatively large tegmen plates show advanced specialization. All the primitive actinocrinitids in which the anus opens directly through the tegmen, *Abactinocrinus*, *Cyrtocrinus*, *Physetocrinus* and *Strotocrinus*, have unusually small primitive tegmen plates.

Abactinocrinus has no known immediate Devonian ancestors. It could definitely have been related to *Cyrtocrinus* and eventually *Physetocrinus*. *Cyrtocrinus lobatus* from the Lake Valley formation (early Osagean, New Mexico) still retains the minute tegmen plates, the marked pentalobate outline at the arm levels, the tube-like ambulacral areas on the tegmen, and the eccentric anal opening. The cup of *Cyrtocrinus* is higher and more markedly stellate.

ABACTINOCRINUS ROSSEI Laudon and Severson, n. gen. and n. sp.
Plate 53, figures 8–10; plate 55, figures 22–23

Cup rapidly expanding, height 14 mm., width 31 mm. BB three, equal. RR five, width 7 mm., height 8 mm., separated on posterior by X. IBr_1 hexagonal, 7 mm. width, height 5 mm. $IIBr_2$ flaring abruptly outward, axillary, IIBrr two, directly laterally and terminating the widest part of the cup. Primary IBr large, hexagonal, in contact with R, IBr_1 and iBrr of higher ranges, followed by two in the second range at the level of the ambulacral openings. X slightly higher than wide, followed by two plates in second range, three in third and smaller plates in higher ranges. Rays widely separated on posterior.

Tegmen of unusually small plates, iAmbAmb areas abruptly constricted producing an abruptly pentalobate cross section at arm levels. Ambulacral areas conspicuously raised into tube-like areas that project outward to ambulacral openings.

EXPLANATION OF PLATE 54

All illustrations ×1 unless otherwise indicated.

FIG. *1*—*Platycrinites basicraniatus* Laudon and Severson, n. sp., lateral view of holotype. (p. 533)
2–7—*Platycrinites bozemanensis* (Miller and Gurley). *2*, ×3, lateral view of immature specimen; *3*, lateral view; *4*, ×2, lateral view of immature specimen; *5*, ×2, lateral view of immature specimen; *6*, lateral view; *7*, lateral view of fully adult specimen. (p. 532)
8—*Platycrinites canadensis* Laudon and Severson, n. sp., lateral view of holotype. (p. 532)
9—*Platycrinites incomptus* White, lateral view. (p. 532)
10—*Dichocrinus douglassi* (Miller and Gurley), lateral view. (p. 535)
11–14—*Dichocrinus quadriceptatus* Laudon and Severson, n. sp. *11*, lateral view of holotype; *12*, lateral view of paratype; *13*, ×2, lateral view of immature specimen; *14*, ×3, lateral view of irregular specimen. (p. 534)
15–16—*Dichocrinus bozemanensis* Miller and Gurley. *15*, ×2, lateral view; *16*, posterior view. (p. 533)
17—*Dichocrinus campto* Laudon, lateral view. (p. 534)
18–20—*Eutaxocrinus montanensis* Springer. *18*, lateral views; *19*, posterior view; *20*, lateral view. (p. 523)

AmbAmb plates possess sharp central spines.

Ambulacral openings two to each ray, directed laterally and slightly upward, visible from ventral view.

Anal opens directly through tegmen, lies slightly eccentric between posterior ambulacral tube-like areas, surrounded by minute spinose plates. Plates of cup obscurely stellate. Arms and column unknown.

Discussion.—The single specimen of *Abactinocrinus rossei* was recovered from the acid bath from a slab of limestone collected near the base of the Lodgepole formation from Old Baldy Peak, Bridger range, Montana. Like all crinoids recovered by solution in an acid bath, the replica consists of minute siliceous grains. In such specimens it is difficult to discern crinoid sutures. They must be placed by external form alone since they have all been obliterated. In the dorsal cup this is not difficult but in a tegmen made of minute plates it is all but impossible. The tegmen plates in the figures used to illustrate *A. rossei* have been placed to the best of our ability but in part are undoubtedly guess work.

Occurrence.—Lower portion of Lodgepole formation, Old Baldy Peak, Bridger range, Montana.

Holotype.—USNM No. 123200.

Cactocrinus Wachsmuth and Springer, 1897
Cactocrinus arnoldi Wachsmuth and Springer
Plate 53, figures 1–3

Until comprehensive work concerning the evolution and classification of cactocrinids is completed, there is little reason for attempts at discussion of the problems involved.

Specimens originally described as *C. arnoldi* Wachsmuth and Springer (1890, p. 168) contained the LeGrand specimens with fewer than 30 arms. Within this group many specimens have four arms to the ray but every variation between four, five, and six occurs on some of the rays. *C. arnoldi* from the LeGrand has thicker, heavier arms than its close relative, *C. nodobrachiatus* Wachsmuth and Springer (1890, p. 165). *C. nodobrachiatus* has six arms to each ray and low nodes scattered at intervals along the Brr in the arms. The tegmen plates in *C. arnoldi* are small and primitive, while those of *C. nodobrachiatus* are slightly larger in size and in part slightly nodose.

Several specimens in the Lodgepole formation are referred tentatively to *C. arnoldi*. On at least two there appear to be only four arms to each ray and the iBrr are in contact with tegmen plates. Several specimens have variations of four arms in the ray, in part five arms and in part six arms. On these specimens the separation of the arms at the iBrr areas is less wide. All specimens in the Lodgepole formation have been tentatively referred to *C. arnoldi* unless they have strictly six arms to each ray. In general, specimens referred to *C. arnoldi* have single ridged but strongly stellate plates. The more complex stellate markings appear on the more advanced types.

Occurrence.—Lodgepole formation, distributed widely in the formation, Bridger Mountains, Little Belt Mountains, and Big Snowy Range, Montana.

Figured specimens.—USNM No. 123193, 123194, 123195.

Cactocrinus nodobrachiatus Wachsmuth and Springer
Plate 53, figure 6

Several specimens from the Lodgepole formation are referred to *C. nodobrachiatus* Wachsmuth and Springer (1890, p. 165). The cup is slightly less conical, more broadly expanding. The plates develop more complex stellate marking. There are six arms to the ray with the outside branch of $IIBr_1$ bearing an axillary IIIBr which gives rise to two more unbranched arms. The typical nodes on the Brr are developed to varying extent on several of the specimens. As far as general appearance is concerned this species appears to grade insensibly into *C. arnoldi* and an artificial arbitrary limit has been chosen to designate the two species. Specimens having less than six arms to the ray are automatically referred to *C. arnoldi*.

Occurrence.—Lodgepole formation, Bridger Mountains, Montana.

Figured specimen.—USNM No. 123198.

Cactocrinus ornatissimus Wachsmuth and Springer
Plate 53, figure 4

No specimens that can be truly referred to

C. ornatissimus Wachsmuth and Springer (1890, p. 163) are found in the Lodgepole fauna. However several specimens that are definitely progressive from *C. nodobrachiatus* toward *C. ornatissimus* are present in the faunas. *C. ornatissimus* has a much more widely expanding cup than either *C. arnoldi* or *C. nodobrachiatus*. A sharp conspicuous median ray ridge runs up each ray in the cup and characteristically much more complex stellate markings are present on the other cup plates.

One Lodgepole specimen is figured in which the cup expands rapidly and characteristic *C. ornatissimus* plate markings are developed in a rudimentary fashion. This specimen is irregular in that the X is followed by four plates.

Occurrence.—Lodgepole formation, Bridger Mountains, Montana.

Figured specimen.—USNM No. 123196.

CACTOCRINUS MAGNIDACTYLUS
Laudon and Severson, n. sp.
Plate 53, figure 5

This giant species of *Cactocrinus* is represented by a single specimen in our collections. Although somewhat damaged, it is remarkable that as much of such a large specimen is preserved. It is the largest specimen of *Cactocrinus* known to us.

C. magnidactylus is closely related to *C. imperator* Laudon (1933, p. 51) from the Gilmore City formation of Iowa. It differs in being much larger, robust, and the cup plates tend to be nodose.

Cup conical, height 33 mm., width 45 mm. at arm bases. The arms appear to flare slightly at the top of the cup and reach an estimated length of 150 mm. One arm from which the tip is missing measures 140 mm. in length.

BB apparently three, equal, deeply sculptured with multiple ridges. There are five central ridges that pass vertically up to the R when the R is directly above the middle of B. When the interbasal suture is present there are only four ridges. The BB contact the column without flaring or signs of a basal rim. RR wider than high, height 10 mm., width 11 mm., interradial sutures deeply depressed giving RR a nodose appearance, stellate sculpturing well developed at plate edges and worn smooth at centers of plates. IBrr two, first 8 mm. high, 7 mm. wide, hexagonal; second heptagonal, axillary, width 7 mm., height 6 mm., sutures deeply impressed, giving a pronounced nodose appearance to plates, stellate marking confined to suture areas. IIBr one, axillary, damaged in such a way that true relationships are determinable only with difficulty.

Primary iBr as large as IBr, width 7 mm., height 7 mm., followed by 2, 1, 3 in the higher areas. The cup is damaged in such a way that it is not possible to determine whether the higher Brr are in contact at the arm levels.

The X area is unknown.

The arms are typical of *Cactocrinus*, consisting of unusually small biserial Brr, 15 in a 10 mm. area in the lower arms and 17 in a 10 mm. area in the upper arms. The pinnules are long, slender, closely packed, and all except the terminal pieces bear typical hooks. The arms incurve abruptly at the tips.

The tegmen and tube have not been observed. A parasitic gastropod is in place at the base of the arms in the position that would normally be occupied on non-tube bearing crinoids.

The column consists of unusually closely packed columnals, alternately expanded, 16 columnals in a 10 mm. line length of the column.

Discussion.—The presence of a parasitic gastropod brings up the possibility that this form is not a *Cactocrinus* but has an anal that opens directly through the tegmen. Since *Cyrtocrinus*, *Physetocrinus*, and *Strotocrinus* have few of the characteristic cactocrinoid hooks on the pinnules, we have referred this form to *Cactocrinus*. Although mutilated at the arm bases, there is a slight indication that the cup tends to flare at this point. The general nodose cup appearance, the closely packed columnals, and tendency to flare at the arm levels suggest that *C. magnidactylus* might be related to the forms that eventually developed into *Teleiocrinus* in the late Burlington beds of the Mississippi Valley area. Most of the specimens of *C. imperator* from the Gilmore City formation of Iowa have nodes distributed at intervals along the arms. None appear on *C. magnidactylus*.

Occurrence.—Upper crinoid zone, peak

north of Ross, Bridger Mountains, Montana.

Holotype.—USNM No. 123197.

PLATYCRINITIDAE Bassler, 1938

PLATYCRINITES Miller, 1821

PLATYCRINITES BOZEMANENSIS
(Miller and Gurley)
Plate 54, figures 2–7

P. bozemanensis (Miller and Gurley) (1897, p. 42) is the most abundantly occurring fossil crinoid in the Lodgepole formation. Essentially complete growth stages are present in our collections. *P. bozemanensis* is closely related and ancestral to *P. symmetricus* (Wachsmuth and Springer) (1890, p. 186) from the LeGrand beds in Iowa. *P. symmetricus* develops a deep, more straight-sided cup.

P. bozemanensis is a smooth undecorated form with a conical cup, widest at the arm bases, six arms to the ray with the single arm on the outside of the ray. The Brr are long, angular, uniserial in the primitive growth stages. They progress through angularly cuneiform stages that begin at the tips of the arms and work back down the arm as age progresses to ultimate biserial stages in the adult forms.

Discussion.—*P. bozemanensis* can be differentiated from *P. symmetricus* from the LeGrand beds only in that the cup is deeper and more steeply walled in the adult forms of *P. symmetricus*. In immature forms they cannot be separated. The adult forms of *P. bozemanensis* have unusually long sharp spines developed on the oral plates which contrast sharply with the small nodose oral plates of *P. symmetricus*. *P. bozemanensis* is also related closely to the smooth-plated Burlington forms. *P. burlingtonensis* (Hall) (1897, p. 653) has a lower cup and *P. sarae* (Hall) (1858, p. 673) is more robust throughout. It is also closely related to *P. aqualis* (Hall) (1861, p. 17). Since the cup of *Platycrinites* is essentially stabilized we believe that the most important criterion available for specific differentiation is the nature of the tegmen.

Occurrence.—Lodgepole formation, widely distributed throughout formation. Bridger Mountains, Little Belt Mountains, Big Snowy Mountains, Tobacco Root Mountains, Montana.

Figured specimens.—USNM Nos. 123204, 123205, 123206, 123207, 123208, 123209.

PLATYCRINITES INCOMPTUS
(White)
Plate 54, figure 9

We regard *P. incomptus* (White) (1863, p. 503) as one of the specialized species of *Platycrinites* in which multiple bifurcation is developed. We believe that this evolutionary trend came from a six-armed ancestor closely related to *P. douglassi* (Miller and Gurley) or *P. symmetricus* (Wachsmuth and Springer). We assume that the smooth plated, eight-armed species such as *P. planus* (Owen and Shumard) (1850, p. 57) and *P. halli* (Shumard) (1866, p. 388) were offshoots from the line of ancestry that produced the multiple branched forms. *P. decadactylus* Laudon, Parks, and Spreng (1952, p. 573) from the Banff formation of Alberta may have been directly ancestral to *P. incomptus*. The Banff species has an irregular pattern of arm branching and the fourth bifurcation takes place on $IVBr_3$ and the fifth bifurcation takes place on VBr_3. Since the general trend of evolution in bifurcation of free arms in *Platycrinites* is from the upper arm back toward the cup, we assume that species in which the bifurcation takes place on every other Brr are more advanced. *P. incomptus* has a basal flange which suggests relationships to *P. pratteni* (Worthen) (1860, p. 569) which also has a basal flange. All of these multiple armed forms are so closely related that we question whether such minor character differences will hold constant when large numbers of specimens become available for study.

We have figured the Lodgepole specimen for stratigraphic value only.

Occurrence.—Upper crinoid zone, Lodgepole formation, Bridger Mountains, Montana.

Figured specimen.—USNM No. 123211.

PLATYCRINITES CANADENSIS
Laudon and Severson, n. sp.
Plate 54, figure 8; plate 55, figure 25

P. canadensis is the most primitive form known to us within the very large group of platycrinitids with nodose plates. This group became remarkably abundant during the early Osagean. *P. canadensis* has only

four arms to the ray and they are cuneiform through a considerable portion of the lower arms. The biserial nature is established in the upper arms only. *P. scobina* (Meek and Worthen) (1861, p. 129) from the lower Burlington limestone is the closest relative to *P. canadensis* known to us. *P. canadensis* differs from the younger nodose plated forms in that the nodose plate markings are very delicate, essentially a forecast of the future development within the group.

Cup expanding moderately, much as in *P. bozemanensis*, 6 mm. high, 12 mm. in width at arm bases. BB forming a low pentagonal cup, apparently with a low basal flange. RR comparatively high, height 4 mm., width 4.5 mm. Both BB and RR covered with small delicate nodes, not arranged in a pattern.

IBr one, low, wide, occupying approximately one-third of upper surface of R, suture curved and projecting down into R. IIBr two, second axillary, relatively long. Arms do not bifurcate again beyond IIBrr. First two or three IIBrr simple, non-cuneiform, next three to five markedly cuneiform, upper IIBrr weakly biserial. Pinnules long, slender. Column elliptical, only proximal columnals known.

Discussion.—Specimens closely related to *P. canadensis* are in our collections from the Banff formation, Wapiti Lake area, British Columbia. We have assigned a specific name to this species because we believe it to be ancestral to the large number of more heavily nodose forms that occur in the Osagean and later Mississippian rocks of the Mississippi Valley area. Such species as *P. verrucosus* (White) (1863, p. 502) from the lower Burlington limestone with from four to six arms to the ray, and *P. pocilliformis* (Hall) (1858, p. 528) also from the lower Burlington limestone with five arms to the ray, we assume to be next in the line of ancestry.

P. canadensis is most closely related to *P. scobina* (Meek and Worthen) from the lower Burlington limestone, the only other four armed form with nodose plates. As might be expected *P. scobina* also has numerous, relatively delicate nodes. *P. canadensis* has a more widely expanding cup.

Occurrence.—Lodgepole formation, Bridger range, Montana.

Holotype.—USNM No. 123210.

PLATYCRINITES BASICRANIATUS
Laudon and Severson, n. sp.
Plate 54, figure 1; plate 55, figure 24

The specimens are assigned a new specific name on the basis of their unusual, distinctive cup markings. The cup is primitive, steeply conical, with five arms to the ray in the rays that are available for study. No other known species is similarly marked.

Base steeply conical, expanding to arm bases, height 11 mm., width 15 mm. Arms constricted at mid-length, flaring above constriction and recurved at tips. Length of crown 48 mm. BB flare above a rim-like constriction, marked with multiple vertical ridges. RR wider than high, height 7 mm., width 9 mm. at arm bases, the upper portion smooth, without markings, the lower portion particularly at the R-B suture marked with multiple vertical ridges, R facets unusually wide, occupying fully half of width of R. IBr one, wide, curved. IIBrr two, second much narrower than first, second axillary. IIIBrr unbranched on one side of each of two rays. IIIBrr two on the inside of one ray with the outside arm not bifurcating. IIIBr two on the outside of one ray with the inside arm not bifurcating. Proximal IIIBrr and IVBrr uniserial to cuneiform, changing to biserial on from the third to sixth Brr above the last bifurcation. Pinnules normal for *Platycrinites*.

Column elliptical, twisted, relatively stout.

Discussion.—*P. basicraniatus* has the primitive cup of the normal Kinderhookian species of *Platycrinites* but we know of no other species with similar plate markings.

Occurrence.—Lodgepole formation, upper crinoid zone, Bridger Mountains, Montana.

Holotype.—USNM No. 123203.

DICHOCRINIDAE S. A. Miller, 1889
DICHOCRINUS Munster, 1837
DICHOCRINUS BOZEMANENSIS
Miller and Gurley
Plate 54, figure 10

Several well-defined stocks of dichocrinids appeared in the earliest Mississippian rocks and apparently their ancestors must be sought in Devonian rocks.

The most abundant forms were smooth-

plated, with high conical cups, two uniserial arms to the ray, a low tegmen made of minute plates in which the ambulacral areas raised, the IAmbAmb areas depressed and the oral plates enlarged.

A second steeply conical group represented by such forms as *D. cinctus* Miller and Gurley (1890, p. 21) were identical in character with the smooth-plated forms except that the cup was delicately striated in a distinctive vertical pattern.

A third group had more broadly expanding cups, more heavily plated tegmens, and additional bifurcation to the arms, and the plate surface was more strongly marked with ridges and nodes.

D. bozemanensis Miller and Gurley (1897, p. 44) represents one of the more primitive smooth-plated forms. The cup is steeply conical, elongated. There are two IBrr, the arms are uniserial but become cuneiform in the upper portions on adult forms. The pinnules are slender and short on all of the steeply conical types of *Dichocrinus*.

Discussion.—*D. bozemanensis* is very closely related to *D. delicatus* Wachsmuth and Springer (1897, p. 756) from the LeGrand beds and *D. multiplex* Laudon (1933, p. 54) from the Gilmore City beds, in fact so closely related that we now doubt the advisability of attempting to separate them into three species. *D. laevis* Hall (1858, p. 83) from the lower Burlington formation is also a very closely related direct lineal descendant from this group. *D. inornatus* Wachsmuth and Springer (1890, p. 190), a more specialized form with a more ovate cup and much more closely packed cuneiform Brr, is a valid species and has apparently also been derived from this group. *D. ovatus* Owen and Shumard (1850, p. 61), from the lower Burlington formation, a direct descendant from *D. inornatus*, differs from *D. inornatus* only in that the cup is slightly more oval in outline.

Occurrence.—Lodgepole formation, Bridger Mountains, Montana.

Figured specimens.—USNM Nos. 123217, 123218.

Dichocrinus campto Laudon
Plate 54, figure 17

A single specimen probably referable to the Gilmore City species, *D. campto* Laudon (1933, p. 56) is figured here for stratigraphic value only. These small forms with cirri distributed throughout the length of the cup are thought to be ancestral to *Camptocrinus*.

Occurrence.—Lodgepole formation, Bridger Mountains, Montana.

Figured specimen.—USNM No. 123219.

Dichocrinus quadriceptatus
Laudon and Severson, n. sp.
Plate 54, figures 11–14; plate 55, figure 26

We assume that the four-armed species of smooth-plated dichocrinids were evolved from the two-armed forms by addition of one bifurcation of the arms. Four-armed smooth-plated forms range to the end of the Osagean.

Cup steeply conical, height 6 mm., width 7 mm. at arm bases in holotype. Crown relatively open, arms incurved at tips, length 25 mm. in holotype.

BB two equal, RR five, height 4.6 mm., width 4 mm. in holotype, facet occupying approximately one-third of upper surface of R, curved, only slightly impressed into upper surface of R. X not known.

Arms slender, delicate, uniserial in lower portion, markedly cuneiform in upper portion. IBrr one or two, apparently variable. IIBrr two or three also variable. Pinnules short, slender as in other smooth-plated forms with high conical cups. Column unknown.

Discussion.—*D. quadriceptatus* is most closely related to the lower Burlington specimens of *D. scitulus* Hall (1861, p. 289). Wachsmuth and Springer (1897, p. 767) referred both uniserial four-armed specimens from the lower Burlington and biserial four-armed specimens from the upper Burlington to *D. scitulus*. Since the biserial character is the normal trend to be expected in the evolution of this form we believe that this species should be subdivided. *D. quadriceptatus* differs from the lower Burlington forms of *D. scitulus* in that there are irregularities in both IBrr and IIBrr. Some of the specimens of *D. quadriceptatus* develop far less tightly packed, cuneiform Brr in the upper arms.

It is assumed that *D. quadriceptatus* came from ancestry that eventually gave rise to such forms as *D. crassitextus* White (1865, p. 19) from the upper Burlington limestone, *D. hamiltonensis* Worthen (1883,

p. 313) and *D. blairi* S. A. Miller (1892, p. 646) from the late Osagean beds.

Occurrence.—Lodgepole limestone, Bridger range, Montana.

Types.—Holotype, USNM No. 123213; paratypes, USNM Nos. 123214, 123215, 123216.

DICHOCRINUS DOUGLASSI (Miller and Gurley)
Plate 54, figure 10

D. douglassi (1896, p. 86) was described as *Platycrinites* originally by Miller and Gurley. We have recovered several specimens from the Lodgepole formation of Montana, one from the Banff formation of Alberta, and a very large number of marvelously preserved specimens with stems and arms attached from the Gilmore City formation of Iowa. There is little question but that the original Miller and Gurley specimen is identical.

One specimen is figured here for stratigraphic value. The cup is conical, broadly expanding with the width greater than the height, width at arm bases 12 mm., height 10 mm. There are two IBrr and three IIBrr, the arms are uniserial at the base and markedly cuneiform at the top. Pinnules are more robust than in the smooth-plated forms. A basal flange making a pronounced rim to the base of the cup is present. The plates are marked with multiple, relatively delicate, stellate ridges.

The specimen figured is remarkable in that the upper parts of the arms have been lost during life and small secondary arms have been regenerated. The new secondary regenerated arms have reverted back to the more primitive uniserial character. They are attached to strongly cuneiform stumps.

Discussion.—We are of the opinion that these widely expanding Kinderhookian forms gave rise to the Burlington and Keokuk specialized species with more rugose plate markings such as *D. liratus* Hall (1861, p. 290) from the upper Burlington beds, *D. lachrymosus* Hall (1858, p. 84) from the upper Burlington beds, and *Paradichocrinus polydactylus* (Casseday and Lyon) (1862, p. 18) from the Keokuk beds.

Occurrence.—Lodgepole formation, Bridger Mountains, Montana.

Figured specimen.—USNM No. 123212.

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EXPLANATION OF PLATE 55

All illustrations ×1 unless otherwise indicated.

FIG. *1*—*Culmicrinus jeffersonensis* Laudon and Severson, n. sp., ×⅔, posterior view of holotype. (p. 515)

2—*Holcocrinus longicirrifer* (Wachsmuth and Springer), anterior view. (p. 522)

3–4—*Cradeocrinus dendratus* Laudon and Severson, n. sp. *3*, left posterior view of holotype; *4*, lateral view of paratype. (p. 514)

5—*Bridgerocrinus fairyensis* Laudon and Severson, n. sp., lateral view of holotype. (p. 518)

6—*Pelecocrinus* sp., right posterior view. (p. 515)

7—*Amphelecrinus sacculatus* Laudon and Severson, n. sp., posterior view of holotype. (p. 522)

8–9—*Ramulocrinus livingstonensis* Laudon and Severson, n. sp. *8*, posterior view of holotype; *9*, left posterior view of paratype. (p. 519)

10–11—*Amphelecrinus madisonensis* Laudon and Severson, n. sp. *10*, right anterior view of holotype; *11*, posterior view of paratype. (p. 521)

12–14—*Dinotocrinus logani* Laudon and Severson, n. sp. *12*, lateral view of paratype; *13*, right anterior view of paratype; *14*, left posterior view of holotype. (p. 516)

15—*Linocrinus wilsallensis* Laudon and Severson n. sp., left anterior view of holotype. (p. 517)

16—*Rhodocrinites priminodosus* Laudon and Severson, n. sp., left anterior view of holotype. (p. 525)

17–18—*Rhodocrinites macrotumidus* Laudon and Severson, n. sp. *19*, lateral view of paratype; *20*, anterior and posterior views of two paratypes; *21*, lateral view of holotype. (p. 524)

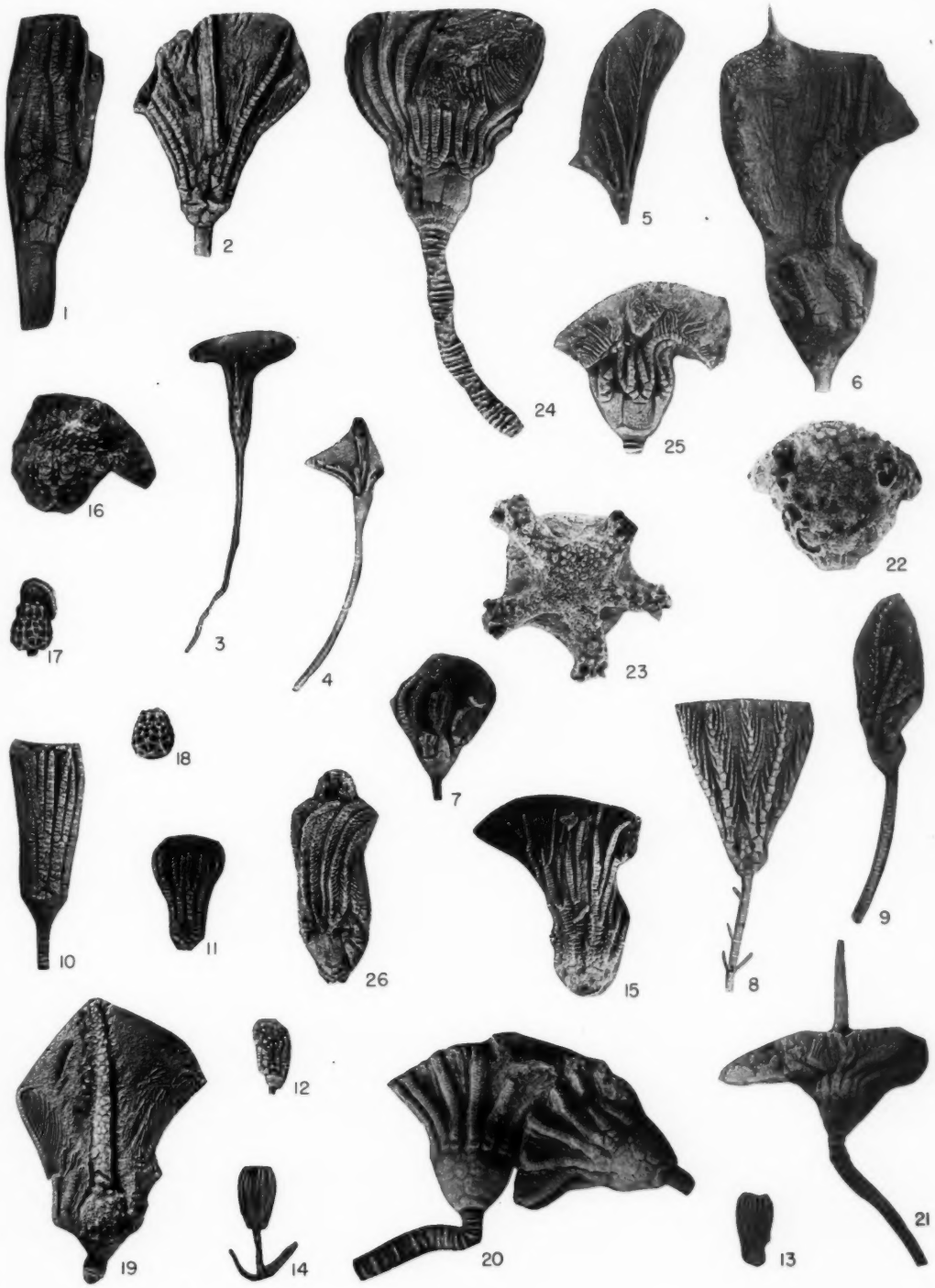
19–21—*Batocrinus gallatinensis* Laudon and Severson, n. sp. (p. 526)

22–23—*Abactinocrinus rossei* Laudon and Severson, n. sp. *22*, posterior view of holotype; *23*, ventral view of holotype. (p. 529)

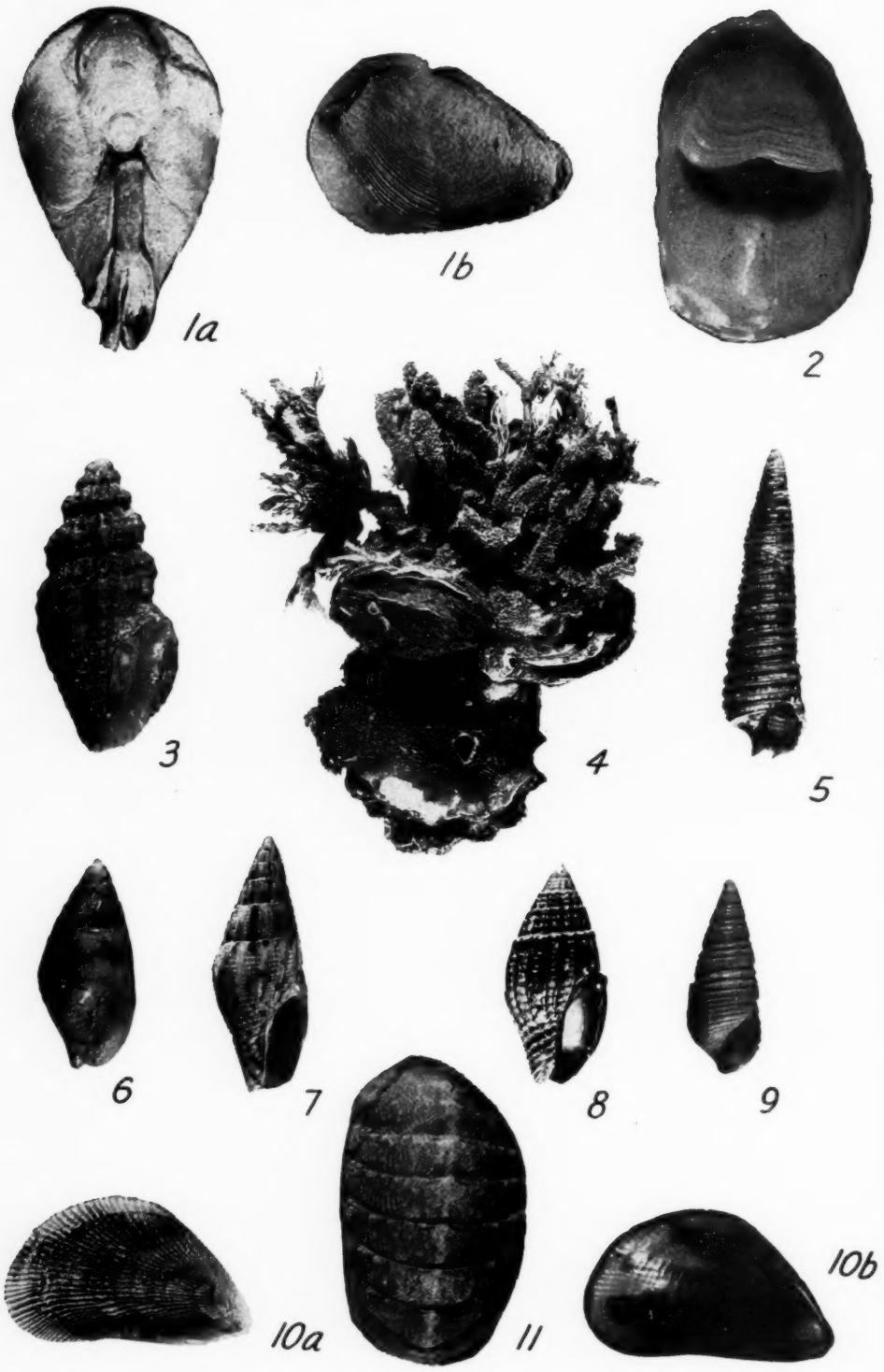
24—*Platycrinites basicraniatus* Laudon and Severson, n. sp., ×½, lateral view of holotype. (p. 533)

25—*Platycrinites canadensis* Laudon and Severson, n. sp., lateral view of holotype. (p. 532)

26—*Dichocrinus quadriceptatus* Laudon and Severson, n. sp., lateral view of holotype. (p. 534)



Laudon and Severson, New Mississippian crinoids from Montana



Puffer and Emerson, Reef Mollusca on the Texas coast

JOURNAL OF PALEONTOLOGY, VOL. 27, NO. 4, PP. 537-544, PL. 56, 1 TEXT FIG., JULY 1953

THE MOLLUSCAN COMMUNITY OF THE OYSTER-REEF BIOTOPE ON THE CENTRAL TEXAS COAST[1]

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ABSTRACT—The molluscan constituents of the oyster-reef biotope studied on the central Texas coast were found to include, among others, 11 living mollusks (one chiton, three pelecypods, and seven gastropods) which are listed, discussed, and illustrated. Physiographic characteristics, salinity, chlorinity, temperature, etc., appear to have a definite effect upon the members of the oyster-reef fauna.

Salinity and temperature evidently are the major controlling factors so far as life on the oyster-reefs of this area is concerned; the extreme shallowness of the bays permits periodic physical and chemical variation to have a more profound effect upon the bay fauna than would normally take place in deeper waters. Knowledge of the tolerances of these mollusks would probably permit recognition of similar environmental conditions in the geologic record.

INTRODUCTION

THE extensive reefs of the oyster, *Crassostrea virginica* (Gmelin), that occur in the shallow water bays of the Rockport, Texas, area (see fig. 1) were studied by the authors during July and August, 1951, and February, 1952. The reefs of Aransas Bay, San Antonio Bay, and Copano Bay were given special attention and the conclusions presented herein are based upon these studies.

Oyster-reefs of this area and their microfauna offer an interesting subject for study in that they are found only in areas where certain environmental conditions exist, and in the fossil record may be used to indicate similar environments of the past. Previous work (Moore, 1907; Moore and Danglade, 1915; Galtsoff, 1931, etc.) on the oyster-reefs of this region has been largely restricted to the commercial aspects of the oyster industry; however, it is to be noted that Ladd (1951) includes a discussion of the oyster-reef facies in his paper on the Texas coast area.

[1] Contribution from the Museum of Paleontology, University of California, Berkeley, California. This investigation was supported by a grant from the American Petroleum Institute, Project 51.

EXPLANATION OF PLATE 56

Specimen and locality numbers refer to the type collections of the Museum of Paleontology, University of California, Berkeley.

FIG. *1a, b—Martesia* (*Diplothyra*) *smithi* (Tryon). *1a*, hypotype no. 32967; locality no. A-7559, 6 mm. ×4.25 mm; *1b*, hypotype no. 33000; locality no. A-7559, 5 mm. × 3.5 mm. (p. 542)

2—Crepidula plana Say, hypotype no. 32968, locality no. A-7439, 18 mm. × 12 mm. (p. 542)

3—Mangelia sp., hypotype no. 32969; locality no. A-7555, 5 mm. × 2 mm. (p. 543)

4—A typical clump of *Crassostrea virginica* (Gmelin) showing attached algae, hydroids, and encrusting organisms. Hypotype no. 32970; locality no. A-7439, greatly reduced. (p. 542)

5—Seila adamsi (H. C. Lea), hypotype no. 32989; locality no. A-7454, 6 mm. × 1.25 mm. (p. 543)

6—Mitrella lunata (Say), hypotype no. 32990; locality no. A-7555, 4 mm. × 1.75 mm. (p. 543)

7—Anachis avara semiplicata Stearns, hypotype no. 32991; locality no. A-7443, 11 mm. × 4 mm. (p. 543)

8—Anachis obesa (C. B. Adams), hypotype no. 32994; locality no. A-7443, 4 mm. × 2 mm. (p. 543)

9—Odostomia (*Menestho*) *impressa* (Say), hypotype no. 32995; locality no. A-7554, 3.5 mm. × 1.25 mm. (p. 543)

10a, b—Brachidontes exustus (Linnaeus). *10a*, hypotype no. 32996; locality no. A-7395, 15 mm. ×9.5 mm.; *10b*, hypotype no. 33997; locality no. A-7395, 15 mm. × 9.5 mm. (p. 542)

11—Ischnochiton (*Ischnoplax*) *papillosa* (C. B. Adams), hypotype no. 32999; locality no. A-7443, 4.25 mm. × 2.75 mm. (p. 543)

The term "reef," as used in this paper, refers to an accumulation of oyster shells which form banks or beds. The upper portion of the bed may be composed of either living or dead individuals, and is elevated at least in part, above the bottom sediments. The surface affords a hard substrate upon which other organisms may dwell. Though these organic structures might be more properly defined as "oyster beds," the commonly used term "oyster-reef" is retained in this paper.

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PHYSICAL ENVIRONMENT

Physiography.—The area is characterized by a number of shallow bays and lagoons into which streams and rivers discharge their loads of sediments (see fig. 1). These bays and lagoons are separated from the Gulf of Mexico by a series of sand barriers which have formed long islands and peninsulas with low relief. Formation of the islands and peninsulas has apparently been influenced by currents, tides, prevailing winds, and the effects of storm action; these processes and agencies have evidently been in operation in this region at least since late Tertiary time (Galtsoff, 1931, pp. 4, 5). The bays of this area are relatively shallow, averaging three or four feet, with a maximum depth of 14 feet. Sediments in the bays for the most part are brown or gray muds; sandy areas are noted adjacent to the barrier islands and the mainland. Water level variations in the region are governed primarily by wind action, resulting in high and low water extremes that may persist for an observed maximum of four days.

Climatic factors.—This region is characterized by great cyclic variations, both seasonal and annual, in amount of rainfall, extremes of temperature, stream runoff and consequently volume of sediments being supplied to or passing through the bays. Temperatures vary considerably depending upon the season of the year; air temperatures as high as 34.7°C. were recorded during the summer of 1951. Gunter and Hildebrand (1951, p. 732) report air temperatures lower than 0°C. during the winter. These temperatures are not to be considered absolute maximum or minimum air temperature readings for the area, but rather as examples of the wide range of temperatures prevalent in the Rockport, Texas, area. The precipitation, as recorded by the Corpus Christi Weather Bureau, for the months of July and August, 1951, was 0.22 and 0.14 inch, respectively. Total precipitation for 1951 was 26.91 inches, the monthly average being 2.24 inches.

Physical-chemical factors.—Table 1 illustrates the extremes in chlorinity, salinity, and temperature recorded in the bays during the months of July and August, 1951. Collier and Hedgpeth (1950, pp. 182–192) give additional temperature, salinity, and other physical-chemical data for the area.

Oyster-reef facies.—Ladd (1951) discusses in some detail the oyster-reef facies of this region; Norris (1953) describes the extent and distribution of some of the prominent reefs. Many of the larger reefs are several miles long, resembling the "long reefs" of Matagorda Bay (Moore, 1907) and are locally more than 20 feet in thickness. These reef-forming shell beds represent the accumulation of numerous individual oyster shells, comprising many generations, and must have been in existence for several hundred years. During the period that the authors studied the Rockport, Texas, area, the reefs of *Crassostrea virginica* were found to be faring poorly, with the exception of those in Copano Bay, a relatively sheltered bay. Evidently oyster productivity had been reduced for some time as there were few commercially productive reefs in Aransas Bay or San Antonio Bay. One explanation for this situation is the recent increase in the salinity of the bays. Ladd (1951, pp. 134, 135) reports salinities of approximately one-half the magnitude of those observed by the

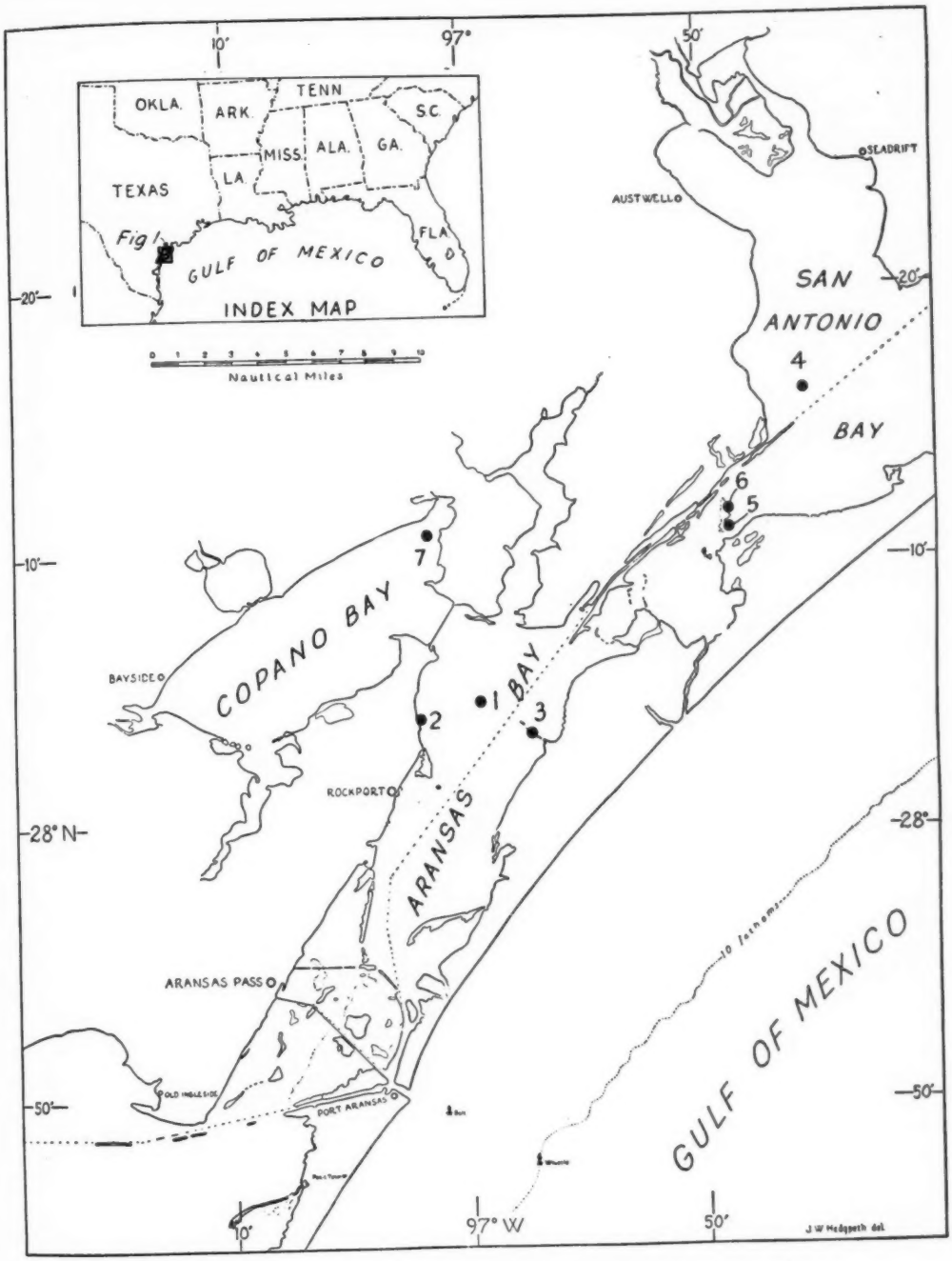

FIG. 1—Map of the area studied showing the location of collecting stations.

present authors. As Ladd's work was undertaken during the summer of 1940, it appears that a gradual increase in the salinity of the bays has occurred during an eleven-year period. This inference is corroborated by local reports and by the immigration into the bays of truly marine forms, including oyster predators from adjacent marine environments. Several types of open Gulf ophiuroids, asteroids, echinoids, octocorals, mollusks, and others, have invaded the bays, indicating a widespread encroachment of marine conditions upon a former brackish-water environment which had been characterized by living *Crassostrea* reefs. The presence of marine conditions, marine organisms, and the resulting change in the local biological food cycle may be the major contributing factors to the temporary extinction of the oyster-reefs; such factors as extremes in temperature, excessive deposition of sediments, and other chemical and physical changes also play an important role in the environment of the bays and have an effect upon the various inhabitants. The periodic freezes are undoubtedly also a contributing factor to the death of many of the shallow water organisms.

It is concordant with the available data pertaining to oyster culture and with the field observations made to conclude that the reefs have not prospered throughout their existence. Cyclic environmental conditions have caused periods of productivity as well as periods during which no living oysters were present, only to be rejuvenated when the return of more ideal conditions permitted the settlement and development of oyster spat resulting in the consequent renewed growth of the reefs.

TABLE 1.

(Data from Shepard, 1952, pp. 1–5)

Area	Chlorinity (‰)		Salinity (‰)		Temperature (°C.)		Depth (feet)
	Surface	Bottom	Surface	Bottom	Surface	Bottom	
Aransas Bay	21.30 to 23.33	21.51 to 23.02	38.44 to 42.11	38.82 to 41.56	29.1 to 32.3	28.9 to 32.7	2.17 to 14.00
Copano Bay	—	21.62 to 22.22	—	39.02 to 40.10	—	—	5.33 to 7.50
San Antonio Bay	1.61 to 22.95	13.24 to 22.46	2.90 to 41.42	23.90 to 40.54	28.5 to 33.8	29.6 to 32.7	0.50 to 7.00

OYSTER REEF COMMUNITY

Ecologic considerations.—The oyster-reef biotope is characterized by encrusting bryozoans, boring sponges, serpulids, annelids, mollusks, and various crustaceans. Thus, these reefs represent one of the few ecologic niches in this area providing a hard substrate; actually such niches also exist on the man-made jetties (cf. Whitten, Rosene, and Hedgpeth, 1950) of the harbors (notably Port Aransas, Texas). However, the fauna of these reefs is restricted because the organisms involved must be of such a eurytopic nature that they may live and take advantage of the conditions offered by a "living" reef. In this regard, it should be noted that the optimum salinity for *Crassostrea virginica* is apparently midway between fresh and marine salt water concentrations (Ladd, 1951, p. 133).

The majority of the gastropod mollusks inhabiting these reefs are eventually dependent upon a "living" reef because there is apparently a ratio between the number of "living" gastropods on a reef and the relative "health" of the reef. A "living" reef will literally teem with tiny individuals, whereas a "dying" reef has a smaller population, and a "dead" reef is apparently bare.

On the basis of the data at hand, salinity and temperature appear to be of consider-

able importance so far as life on an oyster-reef is concerned; other factors appear to play minor roles in restricted cases. Due to the shallowness of the bays, extremes in temperature (Gunter and Hildebrand, 1951, pp. 733–736) may cause the rapid death of organisms; such extremes are apparently fairly periodic in this area. Furthermore, the oysters are subjected to extremes in temperature during the extended periods of low tide, e.g., in August, 1951, temperatures as high as 33.5°C. were recorded on apparently "dying" reefs at depths in excess of 18 inches.

PALEOECOLOGIC CONSIDERATIONS

Limitations of invertebrate faunas.—In the fossil record a considerable number of the organisms inhabiting an oyster-reef would be poorly represented if preserved at all; such forms as hydroids, crustaceans, sponges, and various worms leave little or no trace of their former existence. Conversely, mollusk, bryozoan, and serpulid remains would be the only evidence, in noteworthy numbers, of a former luxuriant biotope. For this reason, paleoecologic interpretations must be based entirely upon our knowledge of living potential fossils and their respective environments. Regardless of the incompleteness of the fossil faunule, it is possible to make certain fairly accurate interpretations of the Tertiary record based upon organisms found as fossils, because many Tertiary genera (and species in some cases) have a geologic range extending into the Recent. However, it must be assumed that the fossil assemblage generally occupied an ecologic niche similar to, if not the same as, that occupied by their extant decendants.

Paleoecologic interpretations.—The presence of *Crassostrea virginica*,[2] an estuarine mollusk, in the fossil record might be interpreted as indicative of former low salinity conditions at the time the reef was alive and flourishing. However, the presence of *Ostrea equestris* Say, which is normally a marine species, attached to the valves of *Crassostrea virginica*, would represent an increase in salinity, bordering on marine conditions, and probably forecasting the imminent extinction of the *Crassostrea* reef.

Upon the temporary extinction of the reef, some of the micromollusks would die and be washed from the oyster reef, but the majority of the microscopic organisms probably would eventually die and be trapped in numerous crevices or other such places within the reef mass. Such individuals would probably be preserved along with the larger fossils in the paleontologic record. The percentage of marine organisms at different horizons within the reef might be used as a method of ascertaining the relative salinity and duration of high salinity, etc. Also, large numbers of herbivorous organisms, such as the snail, *Anachis avara semiplicata* Stearns, would indicate the former existence of plant life which might not be represented in the fossil record.

Using *Crassostrea virginica* and the percentage of eurytopic mollusks, both in numbers and species, as an index to the general salinity conditions, it seems possible to determine the apparent relative ecologic conditions.

ANNOTATED LIST OF MOLLUSCAN SPECIES

Introduction.—Inasmuch as the molluscan constituents of the oyster-reef biotope would be the most conspicuous elements of a potential fossil assemblage, particular attention is given to this group. The species are discussed in a systematic list and recorded (table 2) according to their distribution and relative abundance.

The molluscan community of the oyster beds was found to consist of 11 species: three pelecypods, one chiton, and seven gastropods. In addition, one would expect to find the conch, *Thais haemastoma haysae* Clench,[3] occurring on reefs situated in bays of relatively high salinity. As no living specimens of this snail were encountered at the stations outlined below, the species is not included in the faunal list. In order to

[2] Gunter (1951, p. 516) reports that this species is not known to form reefs in the open sea except just outside Atchafalaya Bay, Louisiana, where the discharge of the Atchafalaya River reduces the salinity of the immediate nearshore waters; Cary (1906, pp. 13–17) also records additional data.

[3] Burkenroad (1931) gives considerable data on the biology of this subspecies and the part it plays as an oyster pest in Louisiana waters.

TABLE 2.—DISTRIBUTION OF SPECIES

Relative abundance based upon living specimens: A = abundant; F = few (3–12 specimens); R = rare (1–2 specimens).

	Aransas Bay			San Antonio Bay			Copano Bay
	Station			Station			Station
	1	2	3	4	5	6	7
Brachidontes exustus	A	A	A	A	A	A	F
Martesia smithi		F			F		A
Crepidula plana		A	A				F
Anachis obesa	A	A	A	A	A	A	
Anachis avara semiplicata	A	A	A		A	A	
Mitrella lunata	A	A	A		A	A	
Odostomia impressa		A	A	A	A	A	
Seila adamsi				R			
Mangelia sp.					R		
Ischnochiton papillosa		R	R				

indicate a potential biocoenosis, only living specimens are recorded for the collecting stations shown on the map. Most of the molluscan members of the reef, except the conch and the oyster, are small to minute in size. The minute gastropods live in the protected nooks and crannies of the oyster clumps (pl. 56, fig. 4). Undoubtedly there are still other minute species living in association with the oysters which were not found during the present studies. Though no concerted attempt was made to recover non-living specimens from the reefs, only one gastropod species, *Triphora perversa nigrocincta* C. B. Adams, other than those reported as living, was found entombed in the reef-trapped sediments. In a thanatocoenosis involving the reef biotope, allochthonous faunal elements, representing the mud-bottom biotope, would undoubtedly accumulate at the edges of the sediment-collecting reefs.

Procedure and method.—For each species in the list below, an illustration is provided, significant synonyms are listed, known geographical range[4] is indicated, remarks pertaining to the ecology of the species in the reef community are given, and occurrences within the area are recorded.

PELECYPODA

BRACHIDONTES EXUSTUS (Linnaeus), 1758
Plate 56, figures 10a, 10b

Brachidontes domingensis (LAMARCK), 1819.

Range.—North Carolina to Texas and the West Indies.

Remarks.—Commonly found attached to oyster shells.

Occurrence.—Aransas Bay, San Antonio Bay, and Copano Bay, Texas.

MARTESIA (DIPLOTHYRA) SMITHI
(Tryon), 1862
Plate 56, figures 1a, 1b

Martesia caribaea authors, not d'Orbigny, 1847.

Range.—New York to Cuba and Texas.

Remarks.—In Copano Bay this species was found to be extremely common as a borer in the oyster shells. At the time it apparently did not infest to any great extent the oyster beds in the other bays.

Occurrence.—Aransas Bay, San Antonio Bay, and Copano Bay, Texas.

CRASSOSTREA VIRGINICA (Gmelin), 1790
Plate 56, figure 4

Range.—Prince Edward Island to the West Indies and Texas.

Remarks.—The reef builder.

Occurrence.—Aransas Bay, San Antonio Bay, and Copano Bay, Texas.

GASTROPODA

CREPIDULA PLANA Say, 1822
Plate 56, figure 2

Range.—Prince Edward Island to Texas.

Remarks.—This species is commonly

[4] The range data are those of Johnson (1934) unless otherwise stated.

found adhering to both dead and living oysters.

Occurrence.—Aransas Bay, San Antonio Bay, and Copano Bay, Texas.

ANACHIS OBESA (C. B. Adams), 1845
Plate 56, figure 8

Anachis cancellata (GASKOIN), 1851; *Anachis ornata* (RAVENEL), 1858.

Range.—North Carolina to Florida and the West Indies.

Remarks.—Fairly common on clumps of oysters. In southwest Florida Perry (1940, p. 147) reports this species living on branching hydroids and on the shells of living *Atrina*.

Occurrence.—Aransas Bay and San Antonio Bay, Texas.

ANACHIS AVARA SEMIPLICATA Stearns, 1873
Plate 56, figure 7

Range.—Gulf of Mexico, Cedar Keys, to Charlotte Harbor, Florida.

Remarks.—Abundant on seaweeds attached to the oysters and occasionally found on oyster shells.

Occurrence.—Aransas Bay and San Antonio Bay, Texas.

MITRELLA LUNATA (Say), 1826
Plate 56, figure 6

Range.—Prince Edward Island to the Gulf of Mexico.

Remarks.—Common on algae growing on oyster shells and on the shells themselves.

Occurrence.—Aransas Bay and San Antonio Bay, Texas.

ODOSTOMIA (MENESTHO) IMPRESSA (Say), 1822
Plate 56, figure 9

Range.—Massachusetts Bay to the Gulf of Mexico.

Remarks.—The most common microgastropod on the reefs, living on the oyster clumps in protected crevices, etc. Perry (1940, p. 114) reports this species as commonly found in association with oysters in southwest Florida.

Occurrence.—Aransas Bay and San Antonio Bay, Texas.

SEILA ADAMSI (H. C. Lea), 1845
Plate 56, figure 5

Seila terebralis (*Cerithium terebrale* C. B. Adams, 1840, not Lamarck, 1804).

Range.—"Massachusetts to Florida," range here extended to the south Texas coast.

Remarks.—Only one lot of four specimens was collected. These were found nestling in protected nooks and crannies in the oyster clumps.

Occurrence.—San Antonio Bay, Texas.

MANGELIA sp.
Plate 56, figure 3

Remarks.—Two specimens of this minute gastropod were found living on a clump of oyster shells in San Antonio Bay; it was not encountered at any of the other stations. Pulley (1952, pl. 5, fig. 3) also records and figures this species from the central Texas coast. It may prove to be a new species.

Occurrence.—San Antonio Bay, Texas.

AMPHINEURA

ISCHNOCHITON (ISCHNOPLAX) PAPILLOSA (C. B. Adams), 1845
Plate 56, figure 11

Range.—Tampa to the Florida Keys and the West Indies.

Remarks.—Only three specimens of this small green chiton were taken on oyster shells; due to its small size and inconspicuous color it may be easily overlooked. Perry (1940, p. 21) reports finding this species adhering to dead shells of *Atrina* in southwest Florida. Hedgpeth (1950, p. 80) records the occurrence of one specimen on the Port Aransas, Texas, jetty and states that it is not rare on old oyster shells in Aransas Bay and in the vicinity of Port Isabel, Texas.

Occurrence.—Aransas Bay, Texas.

LOCALITY STATION DATA

Station 1 (loc. A-7404)[5]—Depth 0′4″. Adjacent water temperatures: 34.7°C. at 0′3″, 33.5°C. at 1′0″, 32.7°C. at 3′0″. Air temperature 32.0°C. 14 August 1951.

Station 2 (loc. A-7443)—Depth 3′3″. Water temperature 18.7°C. at surface. Air temperature 19.8°C. 1 February 1952.

Station 3 (loc. A-7439)—Depth 5′6″. 4 February 1952.

Station 4 (loc. A-7554)—Depth 1′6″. Water temperature 29.2°C. at surface. Air temperature 30.3°C. 23 July 1951.

Station 5 (loc. A-7555)—Depth 1′–3′. Water temperature 30.3°C. at surface. Air temperature 30.1°C. 3 August 1951.

[5] Locality number of the Museum of Paleontology, University of California, Berkeley.

Station 6 (loc. A-7556)—Depth 0′8″. Water temperature 29.9°C. at surface, 33.5°C. at 0′1.5″, 32.2°C. at 0′3″. Air temperature 30.2°C. 3 August 1951.

Station 7 (loc. A-7559)—Depth 6′0″. Water temperature 29.1°C. at surface. Air temperature 29.3°C. Salinity 39.12°/$_{oo}$ bottom. Chlorinity 21.67°/$_{oo}$ bottom. 27 July 1951.

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NOTICE

ALBERTA SOCIETY OF PETROLEUM GEOLOGISTS THIRD ANNUAL FIELD CONFERENCE, AUGUST 21–22

The Third Annual Field Conference of the Alberta Society of Petroleum Geologists will be held on Friday and Saturday, August 21 and 22, in the foothills and mountains of southwestern Alberta. Outcrops of Mississippian, Jurassic, and Cretaceous sediments will be examined. Information may be obtained from L. E. Workman, Canadian Stratigraphic Service Ltd., 1601 14th Street West, Calgary, Alberta, Canada.

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PRIMITIVE CACHE CREEK FUSULINIDS FROM CENTRAL BRITISH COLUMBIA

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ABSTRACT—The fusulinids *Millerella*? sp., *Nankinella* spp., *Staffella* sp., *Fusulinella jamesensis*, n. sp., and *Akiyoshiella toriyamai*, n. sp., from the Cache Creek limestone exposed about three-fourths of a mile southeast of Ft. St. James in central British Columbia, suggest that this part of the Cache Creek group is of Pennsylvanian age and probably should be correlated with the Middle Pennsylvanian.

INTRODUCTION AND ACKNOWLEDGMENTS

UPPER Paleozoic rocks are widespread in British Columbia in a belt from the south-central part of the Province northward to the Yukon Territory and westward to the Pacific coastal area. They are commonly called the Cache Creek group but are also referred to locally by other names. Rocks of similar lithology and ages are widespread in northern Washington to the south and in the Yukon Territory to the north. One of the larger more or less continuous outcrops of Cache Creek rocks in British Columbia is that in the Ft. St. James Map-Area described in detail recently by J. E. Armstrong (1949). Armstrong obtained numerous collections of fossils from the limestones in the region which were identified by C. O. Dunbar, A. E. Wilson, and M. A. Fritz. These fossils suggest that the Cache Creek of this area may contain rocks representing a large part of the upper Paleozoics. Some of the collections identified by Dunbar demonstrate that the Cache Creek rocks exposed at Kloch Mountain and on the eastern side of Trembleur Lake contain a fauna of fusulinids of the subfamilies Neoschwagerininae and Verbeekininae similar to those known for many years from the Orient and to those more recently described by Thompson, Wheeler, and Danner (1950) from northern Washington. Specimens from one of Armstrong's collections obtained from the south end of the hill between Pinchi Lake and Pinchi Village were identified by Dunbar as a form of *Triticites* of probable Upper Pennsylvanian age. Armstrong also mentioned that Dawson (1878) obtained fusulinids from Mt. Pope northeast of Ft. St. James that were later identified by Dunbar as Lower Permian in age.

We visited the limestone locality about three-fourths of a mile southeast of the L.R. Dickenson Store in Ft. St. James during the summer of 1950 and obtained a fauna of fusulinid Foraminifera composed of a new species of the genus described by Toriyama (1952) as *Akiyoshiella*, forms of *Staffella* Ozawa, *Nankinella* Lee, possibly *Millerella* Thompson, and a form or forms that resemble in many respects *Fusulinella bocki* Möller, the type species of *Fusulinella* Möller. This is the only known occurrence of *Akiyoshiella* outside the Akiyoshi limestone of southwestern Japan.

The genus *Akiyoshiella* occurs in the Akiyoshi limestone of southwestern Japan as a part of faunas which contain *Staffella* and forms similar to *Profusulinella* Rauser-Cernoussova and Beljaev, and where it is closely associated with large species of fusulinids that resemble *Fusulinella bocki* Möller.

The general locality from which the fusulinids here described were obtained is the same as the one from which Armstrong reported a blastoid specimen; in fact it was the report of the blastoid which encouraged us to visit the locality. Although we did not find additional blastoid specimens, we did conclude that the outcrop from which we obtained the fusulinids is not far removed stratigraphically from that mentioned by Armstrong. Numerous echinoderm remains are contained in the limestones with the fusulinids, and our fusulinids and the blastoid collected by Armstrong may well be from the same outcrop.

The total rock section represented on the

hill southeast of Ft. St. James probably is only a few hundred feet thick. However, the total thickness of the Cache Creek in the Ft. St. James area was estimated by Armstrong to be many thousands of feet. Numerous other fusulinids are present in the thick limestones exposed in the immediate area of Ft. St. James, and especially to the northeast of Ft. St. James. However, the fusulinids from southeast of Ft. St. James are of such importance to the paleogeography of Canada that we feel the information should be published now rather than at a later date when a more inclusive report is published.

We wish to express our thanks to Dr. J. E. Armstrong who gave many suggestions helpful in our work in the region. His report on the Ft. St. James Map-Area made it possible for us to visit in the short time available some of the better rock exposures. We appreciate the assistance given by residents of the Ft. St. James area. Mr. L. R. Dickenson was especially helpful, and Mr. Dave Hoy accompanied us by boat on one of the longer trips and provided geographical guidance. Financial aid for completion of this work was given by the University of Wisconsin Research Committee from funds furnished by the Wisconsin Alumni Research Foundation. The Phillips Petroleum Company helped finance part of this study in connection with their program of graduate research in geology.

PALEONTOLOGICAL SUMMARY AND COMPARISONS

Neither the ancestral stock of *Akiyoshiella* nor its descendants, if such exist, are known with certainty. The spirotheca of *Akiyoshiella* is thin and does not contain thick tectoria. In parts of the shell of the genotype species, *A. ozawai* Toriyama, and in *A. toriyamai*, n. sp., the spirotheca seems composed of a single layer. Other parts of the same volution may show a two-layered spirotheca composed of tectum and diaphanotheca, with discontinuous upper and lower layers. Since chomata and heavy axial fillings are present in all shells, it is not certain that the upper and lower discontinuous layers are tectoria. The spirotheca of *Akiyoshiella* resembles that of the European species *Fusulina cylindrica* Fisher de Waldheim more closely than spirothecae found in the Middle Pennsylvanian forms of *Fusulina* of America. The over-all aspects of axial fillings, spirothecal structure, septal fluting, shape of the shell, and the nature of coiling of later stages of gerontic individuals of *Akiyoshiella* seem to suggest that from a purely structural basis this genus is somewhat more advanced than the American Desmoinesian forms of *Fusulina* and is related to *Quasifusulina* Chen. Since only three, or possibly four, species of the genus are known, its full range probably has not been established.

We have obtained numerous sections of fusulinids associated with *Akiyoshiella toriyamai*, n. sp., which we are here referring to *Fusulinella* Möller. Of the many dozens of specimens intersected in numerous thin sections, few are well enough oriented so that all of their shell features can be determined. Three species seem to be present in our collections. One has a highly inflated short shell illustrated by figures 16–20 on plate 57. The second form has a distinctly fusiform shell with sharply pointed poles and moderate chomata illustrated by figures 8–15 on plate 57. The third has broad highly asymmetrical chomata and a large moderately inflated fusiform shell as shown by figures 29–31 on plate 57. It is possible, but not probable, that these three groups of specimens represent the same species. We are describing them all as *Fusulinella jamesensis*, n. sp., are designating a holotype specimen from among the second group of specimens mentioned above, and are referring the others to it.

The form or forms of *Fusulinella* associated in the same sample with *Akiyoshiella toriyamai* and here tentatively referred to *Fusulinella* suggest a Pennsylvanian age for the rocks southeast of Ft. St. James. Many of the specimens have the asymmetrical early volutions found in fusulinids from Derryan rocks of New Mexico, Texas, and Oklahoma. However, the general structural features of the Canadian specimens differ in several ways from most typical *Fusulinella* species, particularly by their apparent total lack of distinct septal fluting and by their thin spirotheca without distinct tectoria. Most early American *Fusulinella* and late forms of *Profusulinella* considered ancestral to early *Fusulinella* have septa which are

fluted in their extreme axial zones. Most later American *Fusulinella* have rather distinct fluting in their extreme polar ends. The lack of fluting in the Canadian form or forms is rather clearly shown in the sections illustrated by figures 15, 17, 18, 19, 29, and 31 on plate 57. Furthermore, the spirothecal structures of the Canadian specimens are different from typical Derryan and basal Desmoinesian *Fusulinella*.

The associated staffelloid fusulinids in the collection from southeast of Ft. St. James, here described as *Staffella* sp. and *Nankinella* spp., do not add much information regarding the age of the Ft. St. James rocks. Forms closely similar to these have been found in rocks ranging in age from lower Derryan to upper Virgilian in Kansas, Oklahoma, Texas, and New Mexico, and in rocks of Permian age in Venezuela, Mexico, Texas, New Mexico, and southern British Columbia.

The scarce *Millerella*? sp. does not add any further information concerning the age of these rocks. Corals, brachiopods, algae, echinoderm remains, and numerous other Foraminifera are associated with the fusulinids described below.

The fusulinid fauna collected from southeast of Ft. St. James seems to support a correlation of the Cache Creek rocks exposed there with Middle Pennsylvanian rocks of other localities in America. As mentioned above, fossils collected by J. E. Armstrong from regions north of Ft. St. James indicate that rocks of Upper Pennsylvanian, Lower Permian, and Middle Permian ages are also represented in the Cache Creek. Faunas in the Cache Creek rocks of the Teslin Lake area of northern British Columbia seem to be of Upper Permian age (Watson and Mathews, 1944). Numerous fossils collected from the Cache Creek rocks exposed east of Kamloops seem to indicate a lower Middle Permian age for at least part of the Cache Creek exposed there (Miller and Warren, 1933; Crockford and Warren, 1935; Miller and Crockford, 1936; Cockfield, 1939; Thompson and Verville, 1950), and faunas from the Marble Canyon limestone of the Cache Creek in the Ashcroft area seem to indicate an Upper Permian age (Dawson, 1879; Dunbar, 1932; Thompson and Wheeler, 1942; Thompson, Wheeler, and Danner, 1950[1]). The Tethyan bryozoan fauna described by Fritz (1932) from Vancouver Island was considered by her to be Permian in age and was obtained from rocks probably equivalent in part to the Cache Creek. Kindle (1926) described a brachiopod which is of Permian age from rocks probably equivalent to a part of the Cache Creek from French Mountain in the Stikine River area of British Columbia to the north of Ft. St. James. Smith (1935) described corals of probable Permian age from limestones exposed in an isolated outcrop in the Similkameen district of extreme south-central British Columbia. Fossils from many other localities would also indicate an upper Paleozoic age for the Cache Creek.

SYSTEMATIC PALEONTOLOGY

MILLERELLA? sp.

Specimens possibly referable to *Millerella* are present in the limestone exposed about three-fourths of a mile southeast of the L.R. Dickenson Store in Ft. St. James, but we are unable to determine all of their shell features. One specimen containing at least four volutions is about 0.25 mm. long and 0.85 mm. wide, giving a form ratio of about 0.3. The spirotheca is like that of typical species of the genus.

NANKINELLA spp.

Plate 57, figures 3–7

Specimens here referred to *Nankinella* spp. are common in the collections from southeast of Ft. St. James. They are all congeneric but seem to represent several species. Some of them have large proloculi, whereas others have minute proloculi. Also, the shapes of the inner volutions of some specimens differ. Although we do not have

[1] *Schwagerina andersoni* was described and illustrated as new by Thompson, Wheeler, and Danner (1950, Middle and Upper Permian fusulinids of Washington and British Columbia: Contr. Cushman Found. Foram. Res., vol. 1, pp. 46–63) from the Granite Falls limestone of Washington and the Marble Canyon limestone of British Columbia. This specific name is a homonym of *Schwagerina anderssoni* (Schellwien), [*Fusulina anderssoni* Schellwien, Palaeontographica, Bd. 55, pp. 192–193; *Schwagerina anderssoni* (Schellwien), 1908, Thompson, Jour. Paleontology, vol. 11, p. 122, 1937; Dunbar and Skinner, Texas Univ. Bull. 3701, p. 702, 1937] and Thompson, Wheeler, and Danner are here proposing the new name *Schwagerina royandersoni* for it.

enough well-preserved specimens to describe the form or forms present, we are illustrating five specimens and are including data obtained from four.

STAFFELLA sp.
Plate 57, figures 1, 2

Staffella sp. is scarce in the limestone exposed about three-fourths of a mile southeast of Ft. St. James. The inner volutions are subdiscoidal, and its outer three or four volutions are spheroidal. Its spirotheca is abnormally thick for a shell so small, and its chambers are moderately high. One specimen of five or six volutions is about 1.1 mm. wide and 1.0 mm. long.

FUSULINELLA JAMESENSIS Thompson, Pitrat and Sanderson, n. sp.
Plate 57, figures 8–31

The shell of *Fusulinella jamesensis*, n. sp., is of moderate size for the genus, short, and inflated fusiform; with pointed polar ends, convex lateral surfaces, and slight shifting axis of coiling. Typical shells of five volutions are about 2.3 mm. long and 1.0 mm. wide, giving form ratios of about 2.3. Three other specimens of five volutions average about 2.1 mm. long and 1.0 mm. wide, giving a form ratio of about 2.1. Averages of the form ratios of the first to the fourth volution of these same three specimens are 1.1, 1.4, 1.7, and 2.1, respectively. The form ratios of the first to the fifth volution of the holotype specimen are 1.1, 1.5, 1.8, 2.0, and 2.2, respectively.

The proloculus of the holotype is small and measures about 90 microns in outside diameter. The shell in the holotype specimen expands slowly but about uniformly. The heights of its chambers above the tunnel in the first to the fifth volution measure 42, 68, 107, 147, and 165 microns, respectively. The heights of the chambers in the first to the fifth volution of one specimen of the short and more inflated type tentatively referred to this species measure 44, 53, 89, 137, and 200 microns, respectively. In contrast to these measurements, the chambers of the first to the seventh volution of another specimen tentatively referred to the species measure 35, 56, 82, 110, 142, 172, and 212 microns, respectively.

The spirotheca is composed of the tectum and a lower, much thicker, but seemingly structureless layer. In some specimens with massive chomata, a covering above and below these layers resembles tectoria. However, in areas free from chomata, the spirotheca seems to be composed of only the two layers. The thicknesses of the tectum and diaphanotheca in the second to fifth volution of the holotype specimen measure about 18, 24, 26, and 27 microns, respectively. These same layers measure about 11, 16, 23, 34, 34, and 36 microns, respectively, in the first to the sixth volution of the specimen illustrated by figure 31 on plate 57. The spirotheca is thickest in the area of the tunnel, and it thins rapidly from there toward the poles.

The septa are composed of the tectum, an extension of the diaphanotheca down the posterior side of the tectum, and a short extension of the diaphanotheca down the anterior side of the tectum. They seem to be plane throughout their lengths in all volutions. The septal counts of the first to the fifth volution of three typical specimens average 7, 12, 12, 13, and 15, respectively.

The tunnel is narrow in the inner volutions, but it becomes wider in outer volutions. Its path is only slightly irregular. Chomata are found in all parts of the shell except for the outer few chambers. In the holotype specimen and in closely similar

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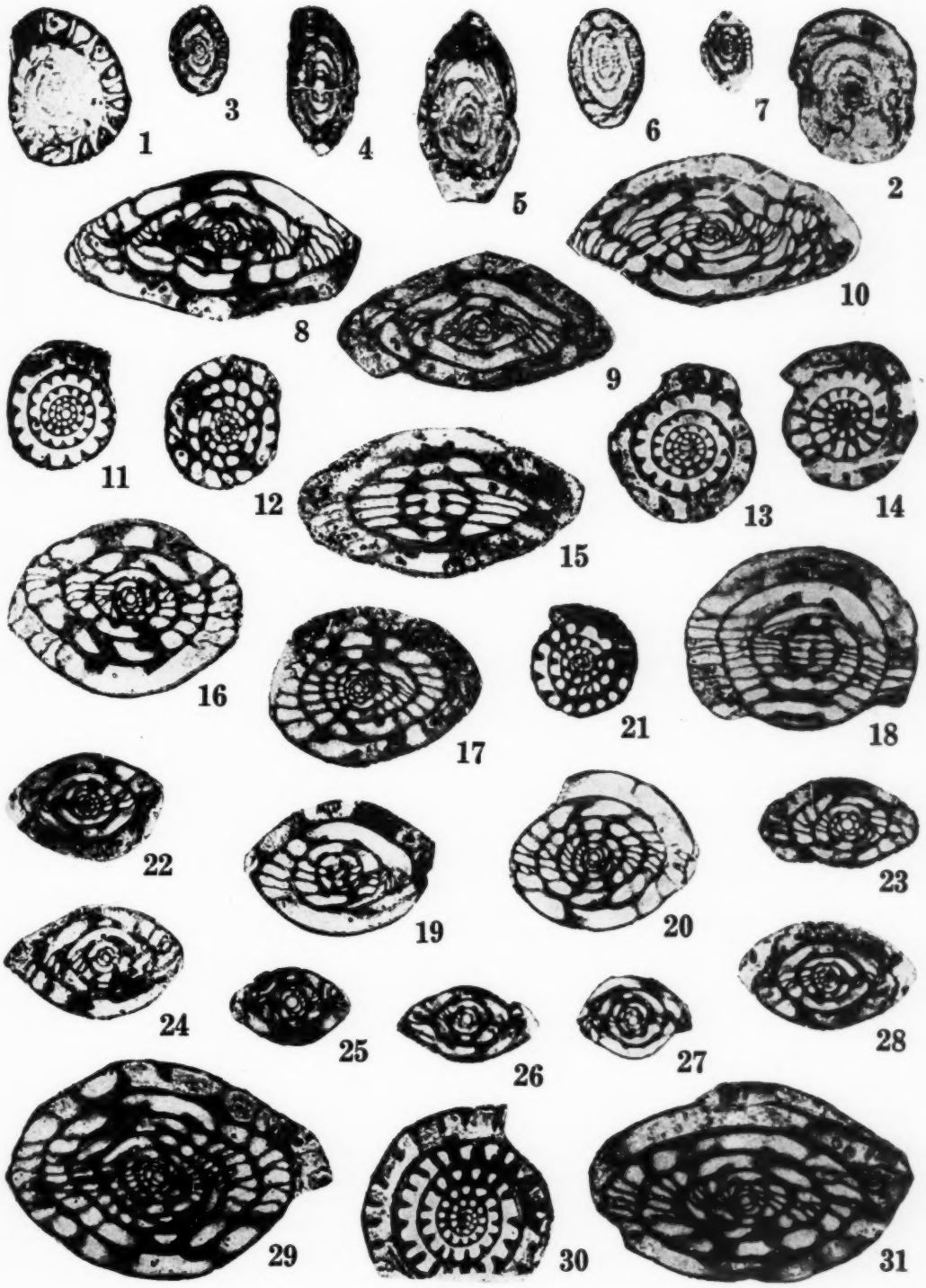
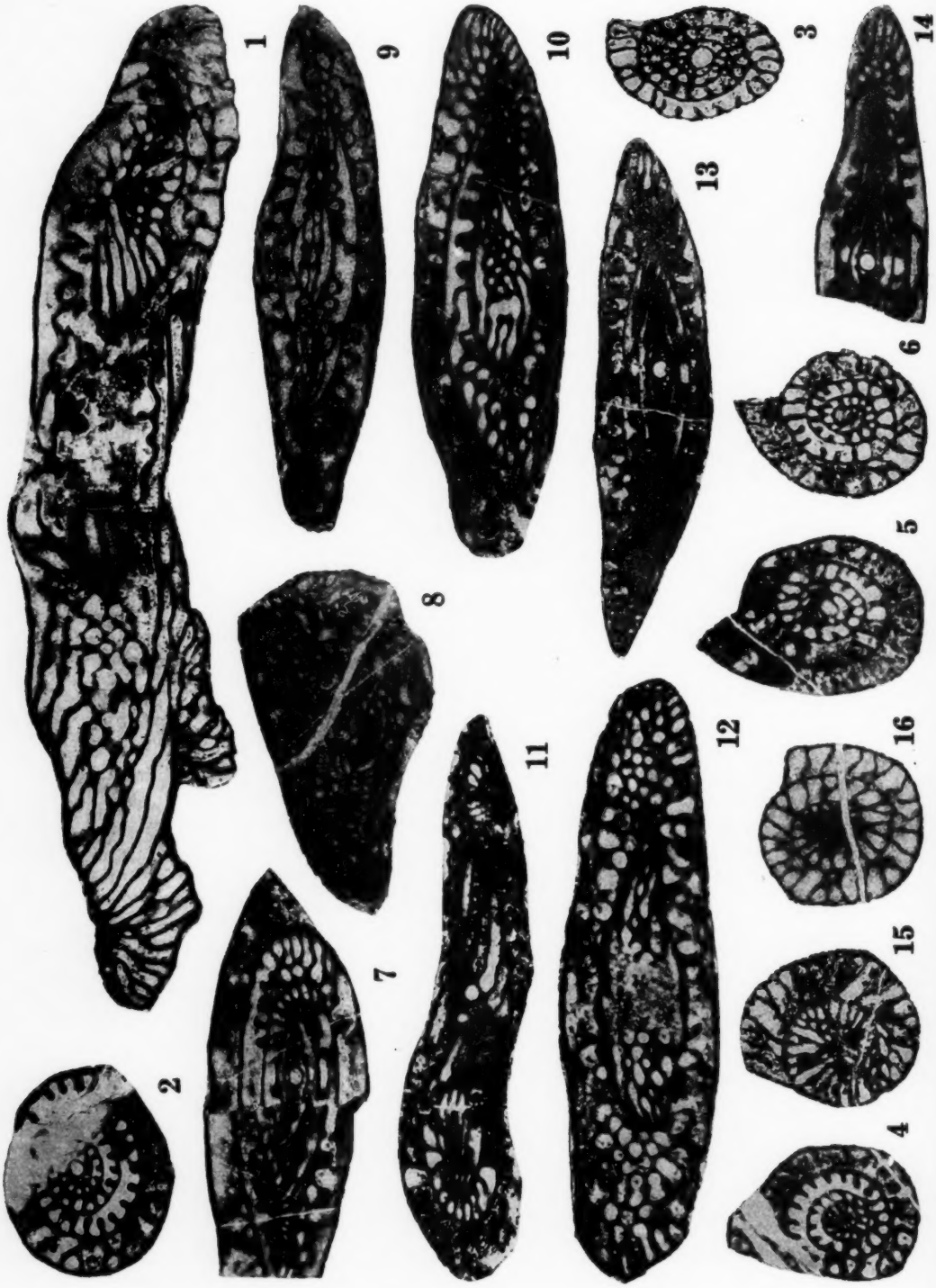
EXPLANATION OF PLATE 57

All figures are unretouched photographs, ×20.

FIGS. *1, 2*—*Staffella* sp. *1*, slightly oblique sagittal section; *2*, axial section. (p. 548)
3–7—*Nankinella* spp. *3, 6*, parallel sections; *4, 5, 7*, axial sections. (p. 547)
8–31—*Fusulinella jamesensis*, n. sp. *8*, axial section of the holotype specimen; *9*, 10, axial sections of paratypes; *11–13, 21*, sagittal sections of paratypes; *14*, parallel section; *15*, tangential section of a paratype; *16–20*, oblique and tangential sections of an abnormally inflated form referred to this species with question; *22–28*, axial sections probably conspecific with the holotype; *29, 31*, oblique axial sections of a form referred with question to this species; *30*, parallel section of same form as *29, 31*. (p. 548)



Thompson, Pitrat, and Sanderson, Fusulinids from British Columbia



Thompson, Pitrat, and Sanderson, Fusulinids from British Columbia

TABLE 1.—MEASUREMENTS OF *Nankinella* spp. IN MILLIMETERS

Specimens 1–4 are illustrated by figures *4*, *6*, *3*, and *5* on plate 57.

Specimen	L.	W.	Diam. prol.	Height of volutions					
				1	2	3	4	5	6
1	.52	1.00	.068	.051	.061	.093	.110	.147	—
2	.52	.85	—	—	—	—	—	—	—
3	.44	.61	.068	.035	.047	.072	.119	—	—
4	.79	1.37	—	—	.044	.079	.110	.156	.202

Specimen	Form ratio of volutions						Thickness of spirotheca				
	1	2	3	4	5	6	1	2	3	4	5
1	.4	.4	.5	.5	.5	—	—	.008	.013	.019	—
2	—	—	—	—	—	—	—	—	—	—	—
3	—	.6	.6	.7	—	—	—	—	.015	.015	—
4	—	.5	.6	.6	.6	.6	—	—	—	.023	.031

specimens they are high, narrow, and asymmetrical with steep to vertical tunnel sides and steep poleward slopes. In some specimens referred to this species with question the chomata extend laterally in inner volutions with slowly decreasing height almost to the polar ends. They extend more than half the distance to the poles in outer volutions. In most parts of the shell the chomata extend up the sides of the septa to the tops of the chambers. In some short ellipsoidal specimens which may be referable to this form, like the specimen illustrated by figure 18 on plate 57, the chomata are very narrow with steep tunnel and poleward slopes.

Remarks.—Fusulinella jamesensis, n. sp., resembles in many respects typical species of *Fusulinella* abundant in Derryan and lower Desmoinesian rocks in central and southern United States. It differs from most American *Fusulinella* in having plane septa and in lacking massive tectoria. Japanese rocks commonly considered Moscovian in age contain numerous fusulinids which have been referred to *Fusulinella* and which have septal attitudes and spirothecal structures like those of *F. jamesensis*. The Canadian and Japanese forms undoubtedly are congeneric. Typical specimens of *F. jamesensis* are smaller in size for corresponding volutions, have more narrow chomata, and have relatively more inflated chambers than most Japanese forms referred to *Fusulinella*. Also, the inflated and short specimens here referred with question to *F. jamesensis* are considerably more inflated than most forms known from Japan. However, the rather large specimens with highly asymmetrical chomata referred with question to this species resemble somewhat closely *F. biconica* (Hayasaka) from the Akiyoshi limestone of southwestern Japan. Further information concerning the Canadian specimens must be obtained before more detailed comparisons are made with *F. biconica*.

Comparisons of *Fusulinella jamesensis* with typical American forms of *Fusulinella* do not seem advisable before a better definition of this form is established.

EXPLANATION OF PLATE 58

All figures are unretouched photographs, ×20.

FIGS. *1–16—Akiyoshiella toriyamai*, n. sp. *1*, tangential section of a large paratype showing erratic coiling of outer parts of shell; *2–6*, centered and near centered sagittal sections of paratypes; *7*, oblique axial section of a paratype; *8*, sagittal section of inner volutions and parallel section of outer asymmetrical and irregular volutions of a paratype; *9–12*, tangential sections of paratypes; *13*, axial section of the holotype; *14*, axial section of a paratype; *15*, *16*, parallel sections of paratypes, the last of which shows heavy axial fillings. (p. 550)

TABLE 2.—MEASUREMENTS OF *Fusulinella jamesensis*, n. sp., IN MILLIMETERS
Specimens 1–5, 7, 8, 15–17, are illustrated by figures *8–12, 16, 18, 29, 31, 30*, on plate 57. Specimen 1 is the holotype.

Specimen	L.	W.	Diam. prol.	Height of volutions							Form ratio of volutions				
				1	2	3	4	5	6	7	1	2	3	4	5
1	2.32	1.04	.091	.042	.068	.107	.147	.165	—	—	1.1	1.5	1.8	2.0	2.2
2	2.05	.99	.086	.037	.051	.072	.126	.137	—	—	1.1	1.4	1.6	2.2	2.1
3	2.05	1.05	.065	.046	.060	.078	.112	.150	—	—	1.2	1.4	1.7	2.1	2.0
4	—	.81	.088	.038	.045	.078	.113	.155	—	—	—	—	—	—	—
5	—	.97	.075	.030	.054	.082	.100	.144	—	—	—	—	—	—	—
7	1.78	1.27	.082	.044	.053	.089	.137	.200	—	—	—	—	—	—	—
8	1.66	1.30	—	—	—	—	—	—	—	—	—	—	—	—	—
15	—	1.56	—	.035	.056	.082	.110	.142	.172	.212	—	—	—	—	—
16	2.37	1.30	.114	.040	.065	.086	.130	.165	.186	—	1.2	1.6	1.8	1.6	1.9
17	—	1.32	.098	.040	.075	.103	.147	.177	—	—	—	—	—	—	—

Specimen	Thickness of spirotheca							Septal count					Tunnel angle (degrees)			
	1	2	3	4	5	6	7	1	2	3	4	5	1	2	3	4
1	—	.018	.024	.026	.027	—	—	—	—	—	—	—	23	27	34	38
2	—	.014	.018	.026	.030	—	—	—	—	—	—	—	—	30	—	43
3	.016	.015	.020	.028	.036	—	—	—	—	—	—	—	—	25	32	36
4	.011	.015	.019	.028	.027	—	—	7	11	12	15	—	—	—	—	—
5	—	.016	.015	.023	.028	—	—	7	12	10	11	15	—	—	—	—
7	—	.012	.020	.024	.031	—	—	—	—	—	—	—	—	—	—	—
8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15	—	.018	.027	.028	.032	.035	.028	—	—	—	—	—	—	—	—	—
16	.011	.016	.023	.034	.034	.036	—	—	—	—	—	—	43	35	35	40
17	.010	.020	.027	.030	.038	—	—	9	12	14	19	—	—	—	—	—

AKIYOSHIELLA TORIYAMAI Thompson, Pitrat and Sanderson, n. sp.
Plate 58, figures 1–16

The shell of *Akiyoshiella toriyamai* n. sp., is of medium size and highly elongate irregularly subcylindrical in shape; having a straight to broadly curving axis of coiling in the inner four to five volutions, an irregular to sharply bending axis of coiling in outer volutions, and blunt to rounded polar ends. The peculiarities of the genus described by Toriyama (1953) are displayed to some extent in the present species by the irregular directions taken by the axis of coiling and by the peculiar additions of chambers such as shown in the lower left of the large tangential section illustrated by figure 1 on plate 58. The diameter indicates that this large specimen had six or perhaps seven volutions. It measures about 7.1 mm. long and 1.2 mm. wide, giving a form ratio of about 6.0. The holotype specimen of four volutions is about 4.0 mm. long and 0.8 mm. wide, giving a form ratio of about 5.0. A paratype specimen of four volutions is 3.5 mm. long and 0.9 mm. wide, giving a form ratio of near 4. Both of these last mentioned specimens are planispirally coiled throughout. Several larger specimens, including those illustrated by figures 11 and 12 on plate 58, show sharp changes in the direction of the axis of coiling in outer volutions. One specimen (pl. 58, fig. 8) is symmetrically coiled about the proloculus in its first two volutions, with outer volutions irregularly arranged about them and with axial trends almost at right angles to them. Averages of the form ratios of the first to the fourth volution of three specimens are 2.7, 3.6, 4.2, and 4.2, respectively.

The proloculus is relatively large and has an outside diameter of 117 to 156 microns, averaging 122 microns for eight specimens. The shell is loosely coiled throughout its growth as shown by the average heights of 55, 85, 133, 182 and 231 microns for the first to the fifth volutions, respectively, of eight specimens, including the holotype. The chambers are lowest above the tunnel. They increase in height very slowly poleward in the inner four volutions but remain of nearly the same height across the central region of the shell in outer volutions. In the outermost volutions of large specimens, the height of a given chamber varies markedly along the chamber width.

The spirotheca is thin and is composed of a tectum and a thicker lower layer here in-

terpreted as a diaphanotheca because it does not contain an obviously porous structure. In some parts of typical specimens thin discontinuous layers which may represent tectoria are present above and below the diaphanotheca. In many parts of the shells the spirotheca seems to be composed of a single thin layer. The lower tectorium seems to be absent below the diaphanotheca in the tunnel area of some specimens. The diaphanotheca increases in thickness sharply immediately adjacent to the septa, with wedge-like extensions for short distances down both sides of the septa. Average thicknesses of the tectum and diaphanotheca in the first to the fifth volution of eight specimens are 12, 18, 25, 34, and 43 microns, respectively. The proloculus wall is thin and measures about 16 microns in thickness.

The septa are thin and are composed of a single layer. They are fluted in their lower surfaces throughout the length of the shell in what seems to be an almost uniform and regular manner. In the end zones of the shell the fluting is about four-fifths as high as the chambers, but near the tunnel it extends for only about half the height of the chambers The septal counts of the first to the fourth volution of five specimens average 10, 15, 18, and 23, respectively.

The tunnel is narrow in inner volutions but is wide in outer volutions. Its path is almost straight. Averages of the tunnel angles of the second to the fourth volution of two specimens are 39, 40, and 61 degrees, respectively. Chomata occur throughout most of the shell except for the last few chambers. They are narrow and have nearly symmetrical slopes in the center of chambers but spread somewhat irregularly up the septa and laterally along the septa and spirotheca to join with very dense deposits in the axial area. Axial fillings completely fill the chambers in the polar areas of the first four volutions.

Remarks.—Only two, or possibly three, species of the genus *Akiyoshiella* have been described, *A. ozawai* Toriyama and *A.* sp. A Toriyama, and possibly *A. staffi* Ozawa. *A. toriyamai*, n. sp., can be distinguished from *A. ozawai* by its more slender shell and therefore larger form ratio, smaller proloculus, and seemingly heavier axial fillings in its inner volutions.

TABLE 3.—MEASUREMENTS OF *Akiyoshiella toriyamai*, n. sp., IN MILLIMETERS.
Specimens 1–9 are illustrated by figures *9, 4, 6, 2, 14, 1, 12, 13, 7* on plate 58. Specimen 8 is the holotype.

Specimen	L.	W.	Diam. prol.	Height of volutions					Form ratio of volutions			
				1	2	3	4	5	1	2	3	4
1	3.84	.96	—	—	—	—	—	—	—	—	—	—
2	—	.97	—	.047	.081	.149	.219	—	—	—	—	—
3	—	1.01	.135	.058	.088	.133	.219	—	—	—	—	—
4	—	1.23	.133	.056	.077	.112	.177	.231	—	—	—	—
5	3.52	.86	.130	.051	.082	.123	.144	—	3.4	3.7	4.1	4.1
6	7.10	1.18	—	—	—	—	—	—	—	—	—	—
7	4.41	1.11	—	—	—	—	—	—	—	—	—	—
8	3.99	.81	.121	.042	.063	.105	.172	—	2.8	4.1	5.0	4.9
9	3.26	1.15	.117	.047	.077	.133	.217	—	—	—	—	—

Specimen	Thickness of spirotheca					Septal count				Tunnel angle (degrees)			
	1	2	3	4	5	1	2	3	4	1	2	3	4
1	—	—	—	—	—	—	—	—	—	—	—	—	—
2	—	.016	.024	.027	—	11	15	19	26	—	—	—	—
3	—	.018	.022	.038	—	10	15	18	—	—	—	—	—
4	.014	.016	.024	.041	.043	8	13	16	20	—	—	—	—
5	.011	.016	.032	.031	—	—	—	—	—	—	33	34	61
6	—	—	—	—	—	—	—	—	—	—	—	—	—
7	—	—	—	—	—	—	—	—	—	—	—	—	—
8	.011	.018	.018	.026	—	—	—	—	—	—	45	46	—
9	.011	.017	.028	.032	—	—	—	—	—	—	64	—	—

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NOTICE

SCIENTIFIC MANPOWER COMMISSION

The Scientific Manpower Commission, recently organized by eight major scientific societies, has opened an office in Washington at 1530 P Street, N.W., and has embarked upon a broad program designed to assure the nation of an adequate supply of scientists. Howard A. Meyerhoff, formerly administrative secretary of the American Association for the Advancement of Science, is president of the commission.

Sixteen scientists, nominated by the participating societies, will make up the commission, which will study the nation's needs for scientists in education, industry, government service, and the armed forces, and will direct its efforts toward bringing the scientific manpower supply and demand into adjustment under changing international economic conditions.

Incorporated in the District of Columbia, the Scientific Manpower Commission was established through the cooperation of the American Association for the Advancement of Science, American Chemical Society, American Geological Institute, American Institute of Biological Sciences, American Institute of Physics, American Psychological Association, Federation of American Societies for Experimental Biology, and the Liaison Committee of the Mathematical Societies. Other private scientific societies will presumably work through the commission now that it is organized.—*Science* (May 8, 1953).

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FRANCONIAN TRILOBITES FROM MINNESOTA AND WISCONSIN

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ABSTRACT—Upper Cambrian trilobites are described from the *Conaspis* zone and the *Prosaukia* subzone of the Franconian Stage in Minnesota and Wisconsin. Fourteen key species of the *Conaspis* fauna, three of which are new, are included in the genera *Bernia, Conaspis, Kendallia, Maustonia, Parabolinoides,* and *Taenicephalus;* and five of James Hall's type specimens are illustrated. The *Taenicephalus* subzone of the *Conaspis* zone is divided into three teilzones which are, in ascending order, the *Parabolinoides palatus, Maustonia nasuta,* and *Taenicephalus altus* teilzones. Also illustrated are common species of the *Prosaukia* subzone that occur in the non-glauconitic Mazomanie member of the Franconia formation and constitute the *Prosaukia longicornis* biofacies, a lateral equivalent of the *Prosaukia misa* biofacies that occurs in the glauconitic Reno member.

INTRODUCTION

IMPORTANT trilobite species from the Upper Cambrian Franconia formation of Minnesota and Wisconsin have been known for many years, but only recently have attempts been made to illustrate completely the several faunas. Species that occur in Minnesota were described by Nelson (1951) and by Bell, Feniak, and Kurtz (1952), but the *Conaspis* zone and *Prosaukia* subzone faunas are better developed in Wisconsin. A field study during 1949 and 1950 demonstrated the need for description of additional trilobites. The purpose of this paper is to describe and evaluate important species of the *Conaspis* fauna and establish a local subzonation. In addition, species of a *Prosaukia* subzone biofacies in Wisconsin are illustrated.

Gilbert O. Raasch, presently with the State Geological Survey of Illinois, has studied the trilobite faunas of the Upper Mississippi Valley for a period of over twenty years, and the Croixan zonation of the Cambrian Correlation Chart (Howell et al., 1944) is largely the result of his work. In September, 1950, Raasch presented a subzonation of the Croixan Series in mimeographed form to Cambrian workers, but unfortunately the details of Raasch's paleontology remain unpublished. Many of these facts pertaining to the *Conaspis* fauna are recorded here for the first time, but my conclusions differ from those proposed by Raasch.

ACKNOWLEDGMENTS

I am grateful for the assistance of Dr. Raasch in obtaining proper collections in the field and for the use of taxonomic information derived from his unpublished notes. The present paper is part of a study of the Franconia formation completed in 1951 under the direction of Dr. W. Charles Bell at the University of Minnesota. Field expenses were generously defrayed by the Minnesota Geological Society. Type specimens from the American Museum of Natural History were obtained through the courtesy of Dr. Norman D. Newell.

FRANCONIA FORMATION

The Franconia formation crops out along the St. Croix and Mississippi rivers in southeast Minnesota and throughout a larger area in west-central Wisconsin (fig. 1). The formation consists of more or less glauconitic sandstones that have an average thickness of about 175 feet. To the north in the St. Croix Valley and to the east in central Wisconsin, greensands interfinger with and are replaced by non-glauconitic sandstone named the Mazomanie formation by Ulrich (1920). Franconia member names proposed by Twenhofel, Raasch, and Thwaites (1935) are geographic names applied to faunal zones: Ironton member (*Camaraspis* zone),

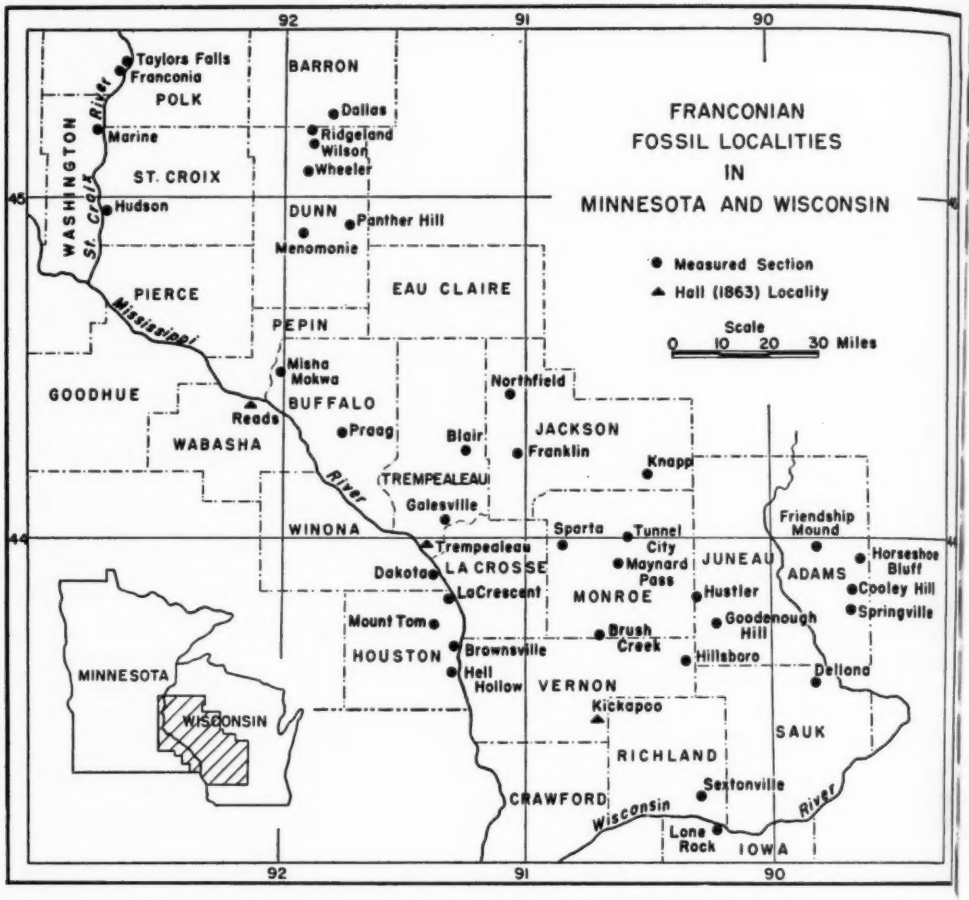


FIG. 1—Locality map.

Goodenough member (*Conaspis* zone), Hudson member (*Ptychaspis-Prosaukia* zone), and Bad Axe member (*Dikelocephalus postrectus* zone). These "members" do not designate rock types, for the distribution of faunal zones in the formation is largely independent of the natural rock units (fig. 2). However, the formation is divisible into five members on the basis of lithic characters (Berg, 1951), and four of these must receive new names. Details of Franconia stratigraphy will be published soon, but the new member names are used in this paper. Summary descriptions of the members are given below in stratigraphic order.

Woodhill member.—Gray to brown, medium- to coarse-grained sandstone, cross-bedded or massive; 0 to 45 feet thick. Type locality: Wood Hill on State Highway 80, [illegible] miles north of Elroy, Juneau County, Wis.

Birkmose member.—Green, highly glau[conitic], cross-bedded, fine-grained sand[stone], and buff, massive, silty sandstone with worm borings, dolomitic, flat-pebble conglomerate at top; 1 to 38 feet thick; persistent lower greensand unit. Type locality: north of Birkmose Park along State Highway 35 in Hudson, St. Croix County, Wis.

Tomah member.—Buff, laminated, micaceous, very fine-grained sandstone, thin-bedded with interbedded shale; 0 to 30 feet thick; underlies both Reno and Mazomanie members. Type locality: Maynard Pass on U. S. Highway 16, 6 miles west of Tomah, Monroe County, Wis.

Reno member.—Green, highly glauconitic, cross-bedded, fine-grained sandstone, and buff, massive, silty sandstone with worm borings, dolomitic, flat-pebble conglomerate at top; 0 to 116 feet thick; uppermost member in southeast Minnesota and western Wisconsin. Type locality: Hell Hollow, 1.5 miles north of Reno, Houston County, Minn.

Mazomanie member.—White to yellow, fine-grained sandstone, lower part thin-bedded and upper part cross-bedded and dolomitic; 0 to 116 feet thick; forms a non-glauconitic facies of the middle and upper Franconia in the northern St. Croix Valley, Dunn County, and central Wisconsin; cross-bedded phase represents the nearest-shore deposition of the upper Franconia. Type locality: School Section Bluff, Mazomanie, Dane County, Wis.

With the exception of the Mazomanie facies, the members are essentially the same units designated by rock type in the papers by Nelson (1951) and Bell, Feniak, and Kurtz (1952).

Conaspis ZONE

The *Conaspis* fauna occurs most abundantly in the Tomah member, but less well preserved specimens are present in the underlying Birkmose and overlying Reno members, making a total thickness for the zone of from 3 to 35 feet. The zone passes into the Mazomanie member northward and eastward and reaches a maximum thickness of about 85 feet at Taylors Falls, Minnesota.

Two divisions are recognized, a lower *Eoorthis* subzone and an upper *Taenicephalus* subzone (Howell et al., 1944). A further refinement of the zonation by G. O. Raasch proposes ten subzones, the faunas of which are characterized by different species. The guiding principle in Raasch's paleontology is the belief that each subzone represents a concise interval of time and is separated from those below and above by a hiatus that may be marked by a flat-pebble conglomerate or bed of greensand. More often there is no physical evidence of this supposed time break. The net result, however, is that each assemblage must be represented by distinct species, and only rarely does a species occur in more than one subzone.

During the present study many collections were made in an attempt to identify these subzones, but after detailed examination of the specimens, it was concluded that many of Raasch's species were based on variable features and that the discrimination of numerous subzones was not practicable. An alternative zonation that is based on a broader interpretation of species is proposed here. The *Eoorthis* subzone is not

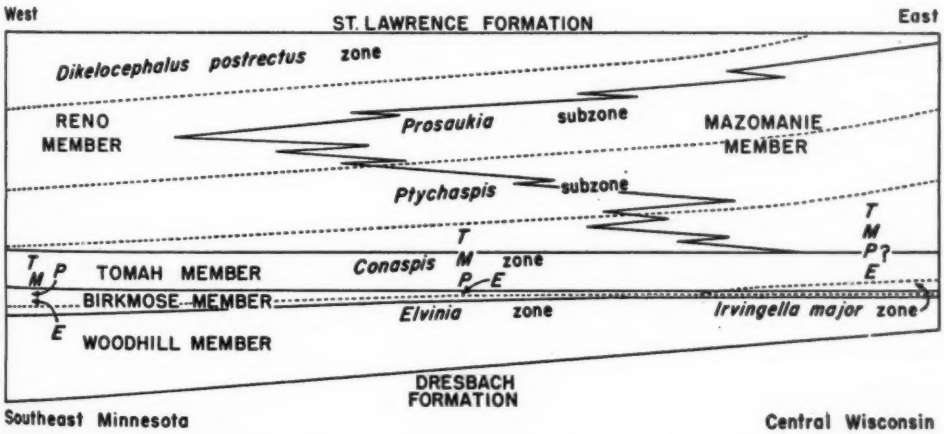


FIG. 2—Diagram showing the distribution of faunal zones within the Franconia formation. *Conaspis* zone subdivisions noted by letter: *E* = *Eoorthis* subzone, *P* = *Parabolinoides palatus* teilzone, *M* = *Maustonia nasuta* teilzone, *T* = *Taenicephalus altus* teilzone. Vertical scale approximately one inch equals 100 feet. Length of section about 80 miles.

subdivided, but within the *Taenicephalus* subzone three assemblages of local stratigraphic importance are recognized. They are designated the *Parabolinoides palatus*, *Maustonia nasuta*, and *Taenicephalus altus* teilzones. The ranges of *Conaspis* zone species are shown in table 1.

The *Eoorthis* subzone is commonly represented only by *Eoorthris remnicha* in sandy dolomite of the upper Birkmose member, but trilobites occur at three localities: *Parabolinoides contractus* (*P. expansa* of Nelson, 1951) in the Birkmose member at Taylors Falls, *Parabolinoides hebe* in the Tomah member at Horseshoe Bluff, and *Parabolinoides hebe*, *Bernia obtusa*, and two species of the underlying fauna, *Irvingella major* and *Comanchia amplooculata*, in the Tomah member at Dellona. The last occurrence appears to be a natural association, and there is no evidence of mechanical mixing of the fossils.

Species of the *Parabolinoides palatus* teilzone occur abundantly in the Tomah member at several localities in Wisconsin from Jackson County southward to the Wisconsin River, but the Birkmose member has yielded only poor specimens of *P. palatus* at Galesville and Misha Mokwa. The teilzone is unknown in the area north of Misha Mokwa.

The *Maustonia nasuta* teilzone is widespread and is characterized by the first appearance of abundant *Maustonia nasuta*. The most common association is found in Tomah sandstone and consists of *Maustonia nasuta*, *Conaspis perseus*, and *Taenicephalus shumardi*. Overlying this assemblage, and

TABLE 1.—RANGES OF *Conaspis* ZONE SPECIES

Species[1]	*Eoorthis* subzone	*Taenicephalus* subzone		
		Parabolinoides palatus teilzone	*Maustonia nasuta* teilzone	*Taenicephalus altus* teilzone
CONASPIS PARVAFRONS Kurtz				xxxxxxxxxxxx
CONASPIS TUMIDUS Kurtz				xxxxxxxxxxxx
TAENICEPHALUS ALTUS Nelson				xxxxxxxxxxxx
Croixana bipunctata (Shumard)			*******	xxxxxxxxxxxx
Maustonia hedra (Kurtz)				**********
Stigmacephalus similis Kurtz			*******	xxxxxxxxxxxx
Wilbernia expansa Frederickson				**********
Wilbernia halli Resser				xxxxxxxxxxxx
Pseudagnostus josepha (Hall)				xxxxxxxxxxxx
CONASPIS PERSEUS (Hall)			xxxxxxx	
KENDALLIA ERYON (Hall)			xxxxxxx	
MAUSTONIA NASUTA (Hall)		*******	xxxxxxxxxxxxxx	
TAENICEPHALUS SHUMARDI (Hall)		xxxxxxxxxxxxxx	xxxxxxxxxxxxxx	
Wilbernia edwardsi (Resser)		**********	**********	
Billingsella cf. B. perfecta Ulrich and Cooper	*****	xxxxxxxxxxxxxx	xxxxxxxxxxxxxx	xxxxxxxxxxx
CONASPIS? ANGULARIS Berg, n. sp.		**********		
KENDALLIA BIFOROTA Berg, n. sp.		xxxxxxxxxxxxxx		
PARABOLINOIDES PALATUS Berg, n. sp.		xxxxxxxxxxxxxx		
BERNIA OBTUSA Frederickson	**********			
PARABOLINOIDES CONTRACTUS Frederickson	**********			
PARABOLINOIDES HEBE Frederickson	xxxxxxxxxx			
Eoorthis remnicha Winchell	xxxxxxxxxx			
Eoorthis wichitaensis Walcott	xxxxxxxxxx			

[1] Capital letters denote species illustrated in this paper. x—species common, *—species rare.

commonly in the lower Reno member, is *Kendallia eryon* with less abundant *T. shumardi* and *M. nasuta*. The teilzone has not been found in the Birkmose member and occurs in the Mazomanie member only at Taylors Falls and Cooley Hill. One collection at Sextonville contains a single specimen of *M. nasuta* with abundant *Parabolinoides palatus* and indicates that even the species characteristic of adjacent teilzones occasionally may be found together.

The *Taenicephalus altus* teilzone occurs in the Tomah member in sections on the Mississippi River and constitutes that part of the *Conaspis* zone described by Bell, Feniak, and Kurtz (1952). The teilzone is poorly represented in the Reno member because good specimens are rarely collected, but it passes northward into the Mazomanie member in the northern St. Croix Valley and Dunn County.

Prosaukia SUBZONE

The fauna of the *Ptychaspis-Prosaukia* zone has been described by Bell, Feniak, and Kurtz (1952) and illustrated by specimens collected from the Reno member in southeast Minnesota. The upper half, the *Prosaukia* subzone, is characterized by the first appearance of saukinid trilobites, a prominent element in the upper Franconian stage and in the overlying Trempealeauan. *Prosaukia misa* and *Ptychaspis miniscaensis* are common species of the subzone in the Reno greensands, but the two species are rare in the non-glauconitic Mazomanie sandstone. Instead the subzone is characterized by an abundance of several different species, the most typical of which is *Prosaukia longicornis*. The following species have been identified from the Mazomanie member.

**Briscoia schucherti* Ulrich and Resser
Chariocephalus whitfieldi Hall
**Dartonaspis knighti* Miller
Ellipsocephaloides gracilis Feniak
**Idahoia* cf. *I. latifrons* (Shumard)
Idahoia wisconsensis (Owen)
**Illaenurus truncatus* Feniak
**Prosaukia anomala* Ulrich and Resser
**Prosaukia curvicostata* Ulrich and Resser
Prosaukia cf. *P. dubia* Ulrich and Resser
**Prosaukia longicornis* Ulrich and Resser
†*Prosaukia misa* (Hall)
Prosaukia tuberculata Ulrich and Resser
Ptychaspis miniscaensis (Owen)
†*Ptychaspis tuberosa* Feniak
†*Stigmaspis hudsonensis* Nelson
Paleostrophia primordialis (Whitfield)

Species marked by an asterisk are abundant only in the cross-bedded Mazomanie sandstone, and those marked by a dagger are found in thin-bedded Mazomanie sandstone as well as in the Reno greensands. The remaining species occur in both types of Mazomanie sandstone and in the Reno member. Three species occur in the Reno member in southeast Minnesota but have not been found in the Mazomanie member: *Prosaukia? ambigua* Ulrich and Resser, *Idahoia hamulus* (Owen), and *Pseudagnostus josepha* (Hall).

There is, then, a lateral segregation of species within the *Prosaukia* subzone that apparently was controlled by sedimentary environment. The two equivalent faunas may be designated biofacies and named for their characteristic species, the *Prosaukia misa* biofacies of the greensands to the south and west, and the *Prosaukia longicornis* biofacies of the cross-bedded, non-glauconitic sandstone to the north and east.

Prosaukia curvicostata was collected by Nelson (1951, p. 768) from cross-bedded Mazomanie sandstone at Marine and Stillwater, Minnesota, but the species was not found elsewhere. Three species, *Briscoia schucherti*, *Illaenurus truncatus*, and *Prosaukia anomala*, occur at Horseshoe Bluff and overlie the *P. longicornis* fauna, but they do not represent the *Briscoia* zone of the Cambrian Correlation Chart (Howell et al., 1944). According to Raasch (personal communication) *Briscoia schucherti* and *Prosaukia anomala* occur in the *Prosaukia* subzone, but *Illaenurus truncatus* occurs in the *Dikelocephalus postrectus* zone in southeast Minnesota (Bell, Feniak, and Kurtz, 1952). Therefore, these species may constitute a facies of the *Dikelocephalus postrectus* fauna, but lacking evidence for a definite assignment, they are included here in the *Prosaukia* subzone.

LOCALITIES

Figure 1 shows the location of measured sections from which fossils were obtained. Collections from eight localities, listed below, have been selected to illustrate the occurrence of species in the *Conaspis* zone

and *Prosaukia longicornis* biofacies. Each locality is assigned a number, preceded by F in the text, and collections are designated by decimal numbers.

Blair (F46)—Roadcuts on State Highway 53, 3 miles south of Blair, Trempealeau County.
F46.1—Tomah member, 21 feet above base.
Conaspis perseus
Croixana bipunctata
Taenicephalus shumardi
Wilbernia edwardsi
Billingsella cf. *B. perfecta*
F46.2—Tomah member, 22 feet above base.
Kendallia eryon
Taenicephalus shumardi
Stigmacephalus similis

Dellona (F207)—Outcrops on County Road P, 3.5 to 4 miles west of Lake Delton, Dellona Township, Sauk County.
F207.1—Tomah member, loose slab.
Parabolinoides hebe
Parabolinoides contractus
Eoorthis remnicha
F207.2—Tomah member, loose slab.
Bernia obtusa
Comanchia amplooculata
Irvingella major
Parabolinoides hebe
Eoorthis remnicha
Eoorthis wichitaensis
F207.3—Tomah member, loose slab.
Parabolinoides hebe
Eoorthis remnicha
Eoorthis wichitaensis

Franklin (F73)—Roadcuts on County Road C, 12 miles west of Black River Falls, Franklin Township, Jackson County.
F73.8—Birkmose member, top foot.
Eoorthis sp.
F73.2—Tomah member, 1 foot above base.
Kendallia biforota
Parabolinoides palatus
Taenicephalus shumardi
F73.3, 73.4—Tomah member, 9 and 12 feet above base.
Conaspis perseus
Maustonia nasuta
Taenicephalus shumardi
Billingsella cf. *B. perfecta*
F73.5—Reno member, 8 feet above base.
Kendallia eryon
Taenicephalus shumardi
F73.6—Reno member, 12 feet above base.
Taenicephalus altus
Stigmacephalus similis

Horseshoe Bluff (F179)—Shale pit and outcrops on County Road G at Horseshoe Bluff, 12 miles east of Adams, Adams County.
F179.3—Tomah member, 5 feet above base.
Parabolinoides hebe
Eoorthis wichitaensis
F179.4—Mazomanie member, cross bedded, loose blocks in covered interval from 0 to 89 feet above base of member.
Chariocephalus whitfieldi
Idahoia cf. *I. latifrons*
Prosaukia cf. *P. dubia*
Prosaukia longicornis
Prosaukia tuberculata
Ptychaspis miniscaensis
Paleostrophia primordialis
F179.5—Mazomanie member, cross bedded, 90 feet above base.
Ellipsocephaloides gracilis
Prosaukia tuberculata
F179.6—Mazomanie member, cross bedded, 106 feet above base.
Dartonaspis knighti
Ellipsocephaloides gracilis
Idahoia wisconsensis
Paleostrophia primordialis
F179.7—Mazomanie member, cross bedded, 115 feet above base.
Briscoia schucherti
Illaenurus truncatus
Prosaukia anomala

Lone Rock (F83)—Roadcuts on State Highway 137, 1.5 miles south of Lone Rock, in Iowa County.
F83.1—Tomah member, 1 foot above base.
Parabolinoides palatus
Taenicephalus shumardi
Wilbernia edwardsi
Billingsella cf. *B. perfecta*
F83.2, 83.3—Tomah member, 3 and 8 feet above base.
Kendallia eryon
Maustonia nasuta
Taenicephalus shumardi
Wilbernia edwardsi

Maynard Pass (F78)—Roadcuts on U. S. Highway 16, 6 miles west of Tomah, Monroe County.
F78.1, 78.5—Tomah member, 1 and 3 feet above base.
Kendallia biforota
Parabolinoides palatus
Taenicephalus shumardi
Billingsella cf. *B. perfecta*
F78.2—Tomah member, 16 feet above base.
Conaspis perseus
Maustonia nasuta
Taenicephalus shumardi
Wilbernia edwardsi
F78.3, 78.6—Reno member, 1 and 4 feet above base.
Kendallia eryon
Maustonia nasuta
Taenicephalus shumardi
Wilbernia edwardsi
Billingsella cf. *B. perfecta*

Ridgeland (F32)—Roadcuts on State Highway 25, 1 mile north, and on County Road V, 1 mile east of Ridgeland, Dunn County. Reno and Mazomanie members interfinger, and collections are listed in stratigraphic order.
F32.1—Mazomanie member, thin bedded, 10 feet above base of exposure.
Conaspis tumidus
Croixana bipunctata
F32.2—Reno member, 16 feet above base of exposure; *Ptychaspis granulosa* teilzone fauna.

F32.4—Reno member, 29 feet above base of exposure.
Idahoia wisconsensis
Prosaukia tuberculata
Ptychaspis tuberosa
F32.3, 32.5—Mazomanie member, thin bedded, 48 feet above base of exposure.
Ellipsocephaloides gracilis
Prosaukia misa
Prosaukia tuberculata
Ptychaspis cf. *P. miniscaensis*
Stigmaspis hudsonensis
F32.6—Mazomanie member, cross bedded, 63 to 68 feet above base of exposure.
Chariocephalus whitfieldi
Dartonaspis knighti
Idahoia wisconsensis
Prosaukia cf. *P. dubia*
Prosaukia tuberculata
Prosaukia longicornis

Wheeler (F48)—Roadcuts on State Highway 25, 3 miles north of Wheeler, Dunn County.
F48.2—Birkmose member, 16 feet above base.
Eoorthis remnicha
Billingsella cf. *B. perfecta*
F48.3, 48.4—Birkmose member, 17 feet above base.
Maustonia nasuta
Billingsella cf. *B. perfecta*
Otusia sp.
F48.5, 48.6, 48.7—Tomah member, 6, 9, and 14 feet above base.
Conaspis tumidus
Croixana bipunctata
Taenicephalus altus
Wilbernia halli
Finkelnburgia sp.
F48.9—Mazomanie member, 10 to 13 feet above base.
Conaspis parvafrons
Taenicephalus altus
Wilbernia halli

Fossil localities in the St. Croix Valley and southeast Minnesota are listed by Nelson (1951) and Bell, Feniak, and Kurtz (1952). Additional localities in Wisconsin are:

Brush Creek (F180)—Roadcuts along State Highway 33 in Brush Creek Valley east of Cashton, Monroe County.
Cooley Hill (F81)—Shale pit and roadcut on County Road B, 2 miles south of Grand Marsh, Adams County.
Dallas (F23)—Shale pit on County Road A, 1 mile east of Dallas, Barron County.
Friendship Mound (F80)—South end of Friendship Mound, just north of Friendship, Adams County.
Galesville (F76)—Roadcut on U. S. Highway 53, 1.2 miles east of Galesville, Trempealeau County.
Goodenough Hill (F52)—Roadcuts on State Highway 71, 6 miles west of Mauston, Juneau County.
Hillsboro (F187)—Roadcuts on County Road F, 2 miles north of Hillsboro, Vernon County.
Hustler (F79)—Shale pit on County Road H, 4 miles south of Hustler, Juneau County.
Knapp (F188)—Shale pit on ridge north of County Road O, 6 miles east of Millston, Jackson County.
Menomonie (F47)—Shale pit on State Highway 25, 3 miles north of Menomonie, Dunn County.
Misha Mokwa (F181)—Shale pit on County Road K, 0.5 mile north of Misha Mokwa, Buffalo County.
Northfield (F42)—Shale pit on State Highway 27, 2 miles south of Northfield, Jackson County.
Panther Hill (F53)—Roadcut on State Highway 40, 3 miles northwest of Elk Mound, Dunn County.
Praag (F65)—Shale pit on State Highway 88, 0.5 mile south of Praag, Buffalo County.
Sextonville (F178)—Roadcut on U. S. Highway 14, 1 mile south of Sextonville, Richland County.
Sparta (F77)—Roadcut on State Highway 71, 5.5 miles north of Sparta, Monroe County.
Springville (F185)—Shale pit in NE¼ sec. 11, Springville Township, Adams County.
Tunnel City (F82)—Roadcuts on State Highway 21, 0.8 mile west of Tunnel City, Monroe County.
Wilson (F45)—Roadcuts on State Highway 25, 3 miles south of Ridgeland, Dunn County.

SYSTEMATIC DESCRIPTIONS

The most important species of the faunas are described, and only cranidial features are considered because well-preserved free cheeks and pygidia are rare. For new species or in the clarification of previously described species, particularly those of James Hall (1863), a detailed generic description is followed by a summary of distinguishing characters for each species. The descriptive procedure was suggested by A. R. Palmer of the U. S. Geological Survey.

Occurrences are noted by locality and collection numbers and include those given by Nelson (1951) and Bell, Feniak, and Kurtz (1952). Type numbers refer to specimens in the University of Minnesota Geological Museum (UM) or in the American Museum of Natural History (AMNH). Plates are composed of paired stereographic photographs.

Conaspis ZONE SPECIES

Genus BERNIA Frederickson, 1949

BERNIA OBTUSA Frederickson

Plate 59, figure 1

Bernia obtusa FREDERICKSON, 1949, p. 358, pl. 70, figs. 1–6.

Remarks.—*B. obtusa* is distinguished from species of *Parabolinoides* by its short frontal area with ridge-like border and more strongly convex glabella.

Occurrence.—Rare in the *Eoorthis* subzone. Tomah member: Dellona (F207.2), Springville (F185.2).

Figured specimen.—UM T6671.

Genus CONASPIS Hall, 1863

Conaspis HALL, 1863, p. 152.

Type species.—*Conocephalites perseus* Hall, 1863.

Cranidium, excluding posterior limbs, quadrangular in outline, moderately to highly convex transversely and longitudinally. Glabella quadrate, tapering forward, truncate anteriorly, moderately to strongly convex, length about two-thirds to three-fourths the length of cranidium and width one-third or more that of cranidium; anterior pits present. Glabellar furrows moderately impressed, anterior pair very faint or absent, second pair short and bent backward, posterior pair bent backward and may be joined across the glabella by a faint transverse furrow. Occipital furrow broad. Occipital ring nearly as wide as frontal area, may have small node. Frontal area less than one-third length of cranidium. Border equal to or wider than brim, triangular. Fixed cheeks one-fourth width of glabella. Palpebral lobes semicircular, upsloping, anterior to midline of glabella. Palpebral furrows straight, complete. Ocular ridge present. Posterior limbs variable, width about two-thirds or more that of glabella. Posterior furrow broad, shallow. Course of facial suture variable.

Remarks.—The nature of the palpebral furrows is the fundamental character selected by Raasch to distinguish *Conaspis* from *Taenicephalus*. In *Conaspis* the furrows are straight and complete and distinctly separate the palpebral lobes from the fixed cheeks. In *Taenicephalus* the furrows are incomplete, only the anterior and posterior ends are visible, and the short, convex palpebral lobes rise without a distinct break from the fixed cheeks. However, many specimens lack well-preserved palpebral characters, and other cranidial differences must be relied upon for identification. Except for the distinctive *Conaspis? angularis*, the frontal area in *Conaspis* is always less than one-fourth the length of the cranidium whereas the frontal area of *Taenicephalus* ranges between one-fourth and one-third the length of the cranidium. The glabella of *Conaspis* usually has a greater convexity and may have inflated sides, and the border is equal to or wider than the brim but never narrower.

CONASPIS? ANGULARIS Berg, n. sp.
Plate 59, figure 6

Glabella moderately convex, truncate, with strong anterior pits. Frontal area one-fourth to one-third length of cranidium. posterior limbs triangular. Anterior course of facial suture straight or divergent immediately in front of palpebral lobes, then turns sharply inward at marginal furrow.

Remarks.—This species differs from *C.*

EXPLANATION OF PLATE 59

FIGS. *1*—*Bernia obtusa* Frederickson. Cranidium, ×2, UM T6671, Springville (F185.2). (p. 559)

2, 4—*Parabolinoides hebe* Frederickson. Cranidia, ×2, UM T6673a, b, Dellona (F207.2). (p. 564)

3—*Parabolinoides contractus* Frederickson. Cranidium, ×2, UM T6672, Dellona (F207.1). (p. 564)

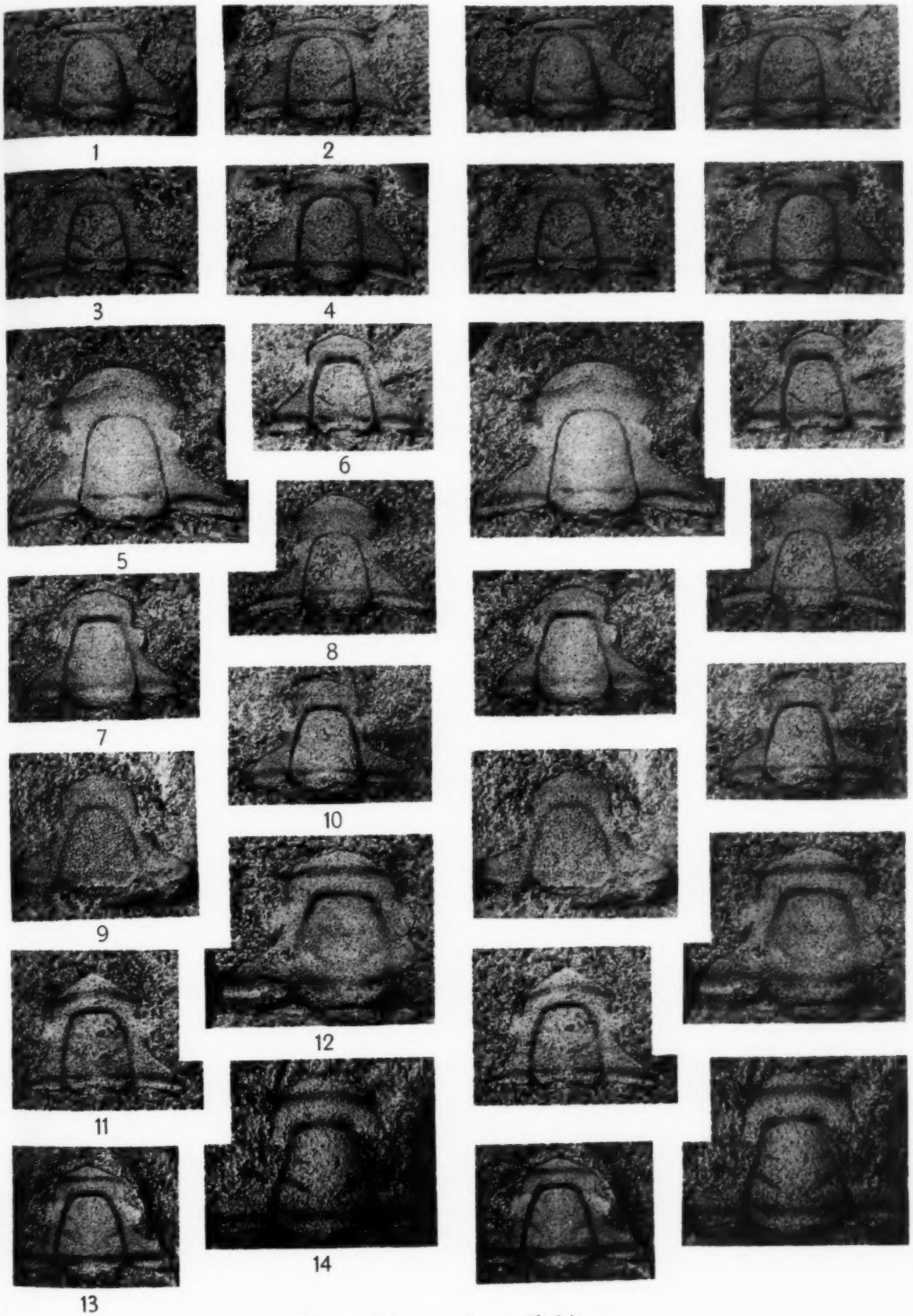
5, 8—*Parabolinoides palatus* Berg, n. sp. Holotype and paratype cranidia, ×2, UM T6676a, b, Franklin (F73.2). (p. 565)

6—*Conaspis? angularis* Berg, n. sp. Holotype cranidium, ×2, UM T6690, Knapp (F188.1). (p. 560)

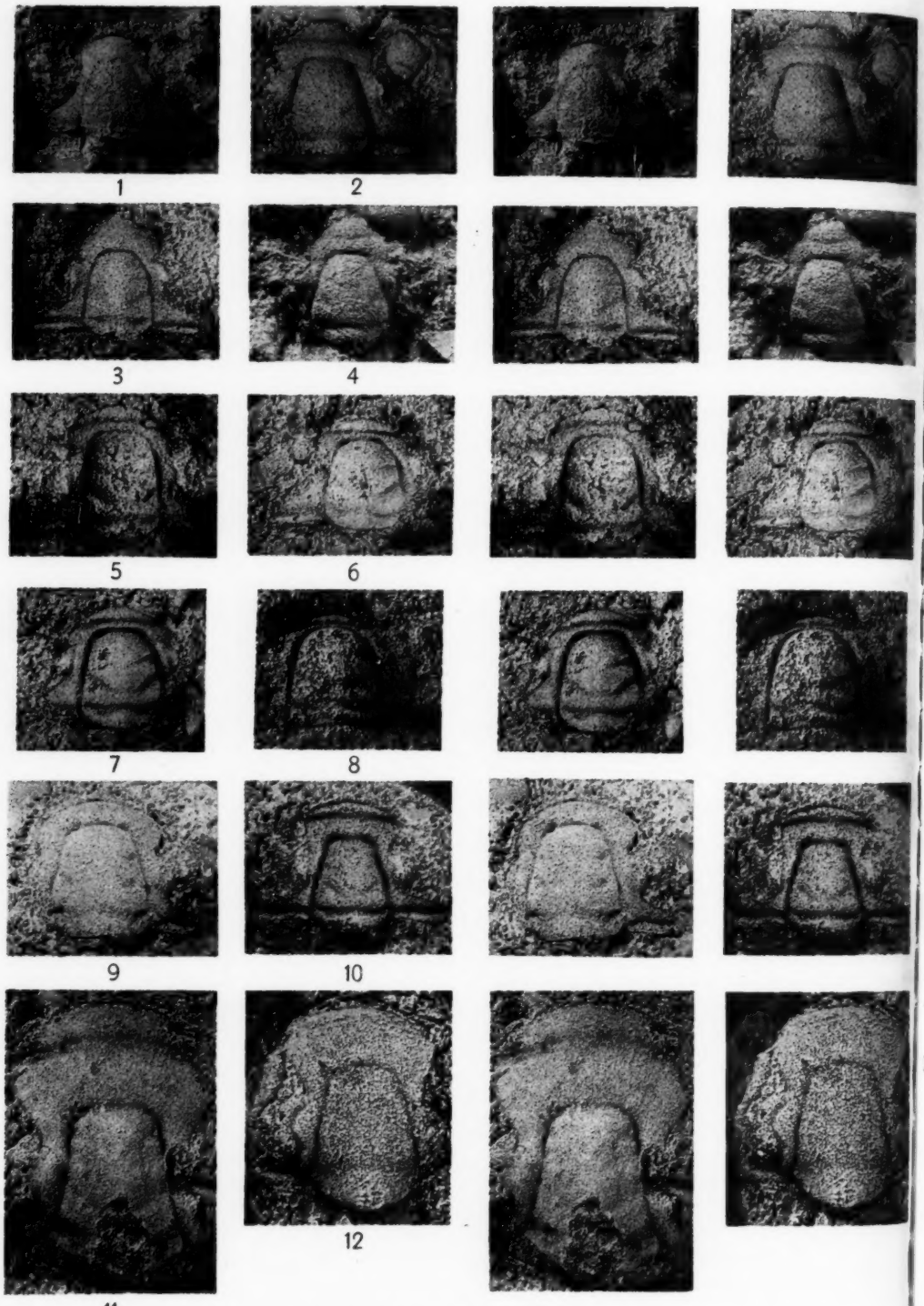
7, 10—*Kendallia biforota* Berg, n. sp. Holotype and paratype cranidia, ×2, UM T6675b, a, Franklin (F73.2). (p. 562)

9—*Kendallia eryon* (Hall). Cranidium, ×2, UM T6682b, Maynard Pass (F78.6). (p. 562)

11–14—*Taenicephalus shumardi* (Hall). *11*, cranidium, ×2, UM T6678, Maynard Pass (F78.6, *Maustonia nasuta* teilzone); *12*, cranidium, ×2, UM T6677b, Maynard Pass (F78.2, *Maustonia nasuta* teilzone); *13*, cranidium, ×2, UM T6674, Franklin (F73.2, *Parabolinoides palatus* teilzone); *14*, holotype cranidium, ×3, AMNH 326/1 (Hall, 1863, pl. 7, fig. 1), Kickapoo. (p. 565)



Berg, Franconian trilobites



Berg, Franconian trilobites

perseus in the longer, more angular frontal area. Although *C.? angularis* resembles species of *Taenicephalus* in the general form of the cranidium, the complete palpebral furrows indicate the probable generic assignment.

Occurrence.—Rare in the *Parabolinoides palatus* teilzone. Knapp (F188.1, 188.2).

Holotype.—UM T6690.

CONASPIS PARVAFRONS Kurtz
Plate 60, figure 9

Conaspis parvafrons KURTZ in Bell, Feniak, and Kurtz, 1952, p. 185, pl. 31, figs. 7a, b.

Glabella moderately convex, rectangular, truncate anteriorly, with anterior pits. Frontal area convex, smooth, length between one-fourth and one-fifth that of cranidium. Posterior limbs narrow. Facial suture strongly divergent anterior to eyes.

Remarks.—This species is distinguished from *C. tumidus*, with which it is associated, by its smooth frontal area. The figured specimen, a broader and more common form of the cranidium than the holotype, is the first illustration of a specimen of known stratigraphic position.

Occurrence.—Common in the *Taenicephalus altus* teilzone. Tomah member: Brownsville (F209.3B), Hell Hollow (F57.2K), Menomonie (F47.2), Mount Tom (F58.2K). Reno member: Praag (F65.1). Mazomanie member: Wheeler (F48.9), Wilson (F45.1, 45.2).

Figured specimen.—UM T6683.

CONASPIS PERSEUS (Hall)
Plate 60, figures 5–7

Conocephalites perseus HALL (part), 1863, p. 153, pl. 7, fig. 17, pl. 8, fig. 33.

Conaspis perseus (Hall) HALL, 1863, p. 152; WALCOTT, 1914, p. 357 (footnote); RESSER, 1937, p. 7; WILSON, 1951, p. 650, pl. 95, fig. 1.

Glabella moderately convex, with anterior pits. Frontal area one-fifth to one-fourth length of cranidium. Posterior limbs triangular. Anterior course of facial suture divergent immediately in front of palpebral lobes, then curves inward. Posterior course nearly straight.

Remarks.—This species is distinguished from *Taenicephalus shumardi*, with which it is associated, by the palpebral lobes and the length of the frontal area.

Hall (1863) suggested that a number of species referred by him to the genus *Conocephalites* might warrant a new generic assignment and proposed the name *Conaspis* for this group. Walcott (1914) selected *Conocephalites perseus* Hall as the type species. Subsequently other new genera were founded on Hall's species, among them *C. shumardi* (the type of *Taenicephalus*) and *C. nasutus* (the type of *Maustonia*). Hall's first figured specimens of these three species were obtained from Kickapoo, Vernon County, Wisconsin. Unfortunately, the outcrop is no longer available, for the *Conaspis*-bearing rock probably is covered by recently deposited alluvium. However, the three species were identified at other localities following a study of the holotypes, and this association is typical of the assemblage herein called the *Maustonia nasuta* teilzone.

Occurrence.—Common in the *Maustonia nasuta* teilzone. Tomah member: Blair (F46.1), Dallas (F23.1, 23.2), Franklin (F73.4), Goodenough Hill (F52.3K), Maynard Pass (F78.2).

Figured specimens.—AMNH 319/3 (holotype), UM T6680a, b.

EXPLANATION OF PLATE 60

FIGS. *1*—*Kendallia eryon* (Hall). Holotype cranidium, ×1, AMNH 327/2 (Hall, 1863, pl. 7, fig. 10), Trempealeau. (p. 562)

2–4—*Maustonia nasuta* (Hall). *2*, *3*, cranidia, ×2, UM T6681a, b, Maynard Pass (F78.2); *4*, holotype cranidium, ×2, AMNH 313 (Hall, 1863, pl. 7, fig. 5), Kickapoo. (p. 563)

5–7—*Conaspis perseus* (Hall). *5*, holotype cranidium, ×4, AMNH 319/3 (Hall, 1863, pl. 7, fig. 17; pl. 8, fig. 33), Kickapoo; *6*, *7*, cranidia, ×2, UM T6680a, b, Maynard Pass (F78.2). (p. 561)

8—*Conaspis tumidus* Kurtz. Cranidium, ×2, AMNH 319/1 (Hall, 1863, pl. 7, fig. 18), near Reads. (p. 562)

9—*Conaspis parvafrons* Kurtz. Cranidium, ×2, UM T6683, Brownsville (F209.4). (p. 561)

10—*Taenicephalus altus* Nelson. Cranidium, ×2, UM T6679, Brownsville (F209.1). (p. 565)

11—*Idahoia latifrons* (Shumard). Cranidium, ×1, UM T6693, Minneiska (F66.2B). (p. 566)

12—*Idahoia* cf. *I. latifrons* (Shumard). Cranidium, ×2, UM T6684, Horseshoe Bluff (F179.4). (p. 566)

CONASPIS TUMIDUS Kurtz
Plate 60, figure 8

Conocephalites perseus HALL (part), 1863, p. 153, pl. 7, figs. 18, 19, 23.
Conaspis perseus SHIMER and SHROCK, 1944, pl. 263, fig. 27; NELSON, 1951, p. 775, pl. 107, fig. 11.
Conaspis tumidus KURTZ in Bell, Feniak, and Kurtz, 1952, p. 185, pl. 31, fig. 5.

Glabella highly convex, anterior pits very faint or absent. Frontal area steeply downsloping, about one-sixth length of cranidium. Posterior limbs narrow, about equal in width to frontal area.

Remarks.—This species is distinguished from *C. perseus* by the highly convex glabella, short frontal area, and narrow posterior limbs. The specimen illustrated here was figured by Hall (1863) as *C. perseus*.

Occurrence.—Common in the *Taeniocephalus altus* teilzone. Tomah member: Brownsville (F209.1B), Hell Hollow (F57.1B), La Crescent (F59.6K), Menomonie (F47.2), Mount Tom (F58.2K), Wheeler (F48.6). Mazomanie member: Franconia (F17.12, 17.14, 17.15, 17.16, 17.20), Ridgeland (F32.1), Taylors Falls (F18.13, 18.14, 18.15, 18.16).

Figured specimen.—AMNH 319/1.

Genus KENDALLIA Raasch, 1939

Kendallia RAASCH, 1939, p. 94.

Type species.—*Conocephalites eryon* Hall, 1863.

Cranidium, excluding posterior limbs, quadrangular in outline, elongate, gently convex transversely and longitudinally. Anterior margin pointed or rounded. Glabella elongate, nearly straight-sided, tapering, truncate or rounded anteriorly, gently to moderately convex, with shallow dorsal furrows, width between one-third and one-half and length one-half to two-thirds that of cranidium. Glabellar furrows usually faint or not visible. Occipital furrow broad, straight. Occipital ring widest at midline. Frontal area between one-fourth and one-third length of cranidium, gently convex transversely and longitudinally. Marginal furrow weak or absent when present brim and border are subequal. Fixed cheeks gently convex, horizontal or downsloping, less than one-third width of glabella. Palpebral lobes short, arcuate, situated at anterior third of glabella. Palpebral furrows faint, not complete. Ocular ridge faint. Posterior limbs triangular, width about two-thirds that of occipital ring. Posterior furrow broad, shallow. Anterior course of facial suture slightly divergent in front of palpebral lobes. Posterior course makes an angle of about 45° with longitudinal axis, gently curved.

Remarks.—*Kendallia* was proposed by Raasch at the same time and in the same way as *Maustonia*, and my remarks following the description of *Maustonia* apply equally to *Kendallia*.

KENDALLIA BIFOROTA Berg, n. sp.
Plate 59, figures 7, 10

Glabella gently to moderately convex, truncate anteriorly, dorsal furrow distinct, especially in front of glabella, and with shallow anterior pits. Fixed cheeks upsloping opposite the convex palpebral lobes.

Remarks.—This species is distinguished from *K. eryon* by the presence of anterior pits and differs from *Conaspis? angularis* in its less strongly developed marginal furrow, lower glabellar convexity, and character of the palpebral lobes.

Occurrence.—Common in the *Parabolinoides palatus* teilzone. Tomah member: Franklin (F73.2), Goodenough Hill (F52.2K), Hustler (F79.2), Knapp (F188.2), Maynard Pass (F78.1), Northfield (F42.3).

KENDALLIA ERYON (Hall)
Plate 59, figure 9; plate 60, figure 1

Conocephalites eryon HALL, 1863, p. 157, pl. 7, figs. 10–16, pl. 8, figs. 16, 31.
Conaspis eryon (Hall) HALL, 1863, p. 152; WALCOTT, 1914, p. 358 (footnote).
Orygmaspis eryon (Hall) RESSER, 1937, p. 22; not Shimer and Shrock, 1944, p. 629, pl. 266, figs. 33, 34 (*Parabolinoides hebe*).
Kendallia eryon (Hall) RAASCH, 1939, p. 94.

Glabella very gently convex, truncate or rounded anteriorly, dorsal furrow shallow. Palpebral lobes and fixed cheeks horizontal or downsloping.

Remarks.—This species is characterized by the low convexity of the cranidium and the smooth frontal area. *K. eryon* resembles *Stigmacephalus similis* Kurtz but differs in the shorter glabella and the more triangular posterior limbs.

Occurrence.—Common in the *Maustonia nasuta* teilzone. Tomah member: Blair (F46.2), Lone Rock (F83.3), Panther Hill (F53.2). Reno member: Franklin (F73.5), Maynard Pass (F78.3, 78.6). The holotype is from Trempealeau, Wisconsin.

Figured specimens.—AMNH 327/2 (holotype), UM T6682b.

Genus MAUSTONIA Raasch, 1939

Maustonia RAASCH, 1939, p. 94; not Lochman, 1950, p. 331 (*Parabolinoides*).

Type species.—*Conocephalites nasutus* Hall, 1863.

Cranidium, excluding posterior limbs, quadrangular in outline, moderately convex longitudinally and transversely, anterior margin obtusely pointed. Glabella elongate, tapering, truncate anteriorly, length one-half and width one-third to one-half that of cranidium. Glabellar furrows faint, three pairs when present, straight, increasing in length and making increasingly sharper angle with dorsal furrow posteriorly. Occipital furrow broad, shallow, straight or curving forward distally. Occipital ring widest in center, may have small node. Frontal area about one-third length of cranidium. Brim convex, downsloping, equal to or wider than border. Border flat or convex, nearly horizontal. Fixed cheeks gently convex, horizontal or upsloping, width less than one-third that of glabella. Palpebral lobes short, situated on anterior one-third line of glabella. Palpebral furrows straight. Faint ocular ridge usually present. Posterior limbs wide, length slightly less than occipital ring. Posterior furrow broad, shallow. Anterior course of facial suture divergent in front of palpebral lobes. Posterior course curving outward and then back around posterior limbs.

Pygidium unknown.

Remarks.—*Maustonia* differs from *Parabolinoides* in the character of the frontal area and posterior limbs. The frontal area of *Maustonia* has a more pointed anterior margin and strongly triangular border. The posterior course of the facial suture of *Maustonia* forms a sigmoidal curve around the posterior limbs whereas the facial suture of *Parabolinoides* is straight or gently curved outward behind the palpebral lobes and produces triangular posterior limbs.

Raasch (1939, p. 94) proposed the name *Maustonia* for "*Conocephalites nasutus* Hall 1863" without giving a summary of characters. As pointed out by Frederickson (1949, p. 361) this omission invalidates the name under Article 25, paragraph c, of the International Rules of Zoological Nomenclature. However, paragraph c has been severely criticized, the Rules are currently being revised, and in this paper both *Maustonia* and *Kendallia* are credited to Raasch (1939). Lochman (1950, p. 331) gave a diagnosis of *Maustonia* "based upon the characters of the genotype," *M. nasuta*, but her species *M. cordillerensis* appears to belong to *Parabolinoides*. Furthermore, her generic diagnosis does not include a reference to the sigmoidal curve so typical of *Maustonia*, but it does refer to pygidial spines characteristic of *Parabolinoides*. Strict interpretation of the Rules presently in effect would seem to validate *Maustonia* Lochman (1950), but Lochman's diagnosis, so legally essential, is indistinguishable from that of *Parabolinoides* Frederickson (1949), and does not fit the type species it was intended to include.

MAUSTONIA HEDRA (Kurtz)

Parabolinoides hedrus KURTZ in Bell, Feniak, and Kurtz, 1952, p. 186, pl. 32, fig. 2a (not 2b, c).

Frontal area one-third or slightly more length of cranidium, marginal furrow deep, curved. Brim convex, downsloping. Border convex, horizontal.

Remarks.—This species differs from *M. nasuta* in its deep, curved marginal furrow and convex border.

Occurrence.—Rare in the *Taenicephalus altus* teilzone. Tomah member: Dakota (F8.2K), La Crescent (F59.5K).

MAUSTONIA NASUTA (Hall)
Plate 60, figures 2–4

Conocephalites nasutus HALL, 1863, p. 155, pl. 7, figs. 3–9.
Maustonia nasuta (Hall) RAASCH, 1939, p. 94.
Parabolinoides parallela NELSON, 1951, p. 776, pl. 107, fig. 13.

Frontal area between one-third and one-fourth length of cranidium. Marginal furrow weak, straight. Brim gently convex or

flat, downsloping. Border flat, horizontal or gently downsloping.

Remarks.—This species is characterized by its straight marginal furrow and flat border.

Parabolinoides parallela Nelson is based on a single specimen associated with *M. nasuta* at Taylors Falls, Minnesota. The holotype apparently is flattened and has distorted posterior limbs, but in all other respects it is identical to *M. nasuta*.

Occurrence.—Common in the *Maustonia nasuta* teilzone. Tomah member: Franklin (F73.3, 73.4), Goodenough Hill (F52.3K), Hillsboro (F187.2, 187.3, 187.4), Hustler (F79.4, 79.5), Lone Rock (F83.2, 83.3), Maynard Pass (F78.2, 78.6), Northfield (F42.5, 42.6), Sextonville (F178.3, 178.4), Sparta (F77.1), Wheeler (F48.3). Mazomanie member: Cooley Hill (F181.1), Taylors Falls (F18.8, 24.7, 24a.8). Rare (one specimen) in the *Parabolinoides palatus* teilzone. Tomah member: Sextonville (F178.2).

Figured specimens.—AMNH 313 (holotype), UM T6681a, b.

Genus PARABOLINOIDES Frederickson, 1949

Parabolinoides FREDERICKSON, 1949, p. 360.

Type species.—*Parabolinoides contractus* Frederickson, 1949.

Cranidium, excluding posterior limbs, quadrangular in outline, moderately convex transversely and longitudinally, anterior margin rounded or broadly pointed. Glabella elongate, straight-sided, gently tapering, rounded anteriorly, length one-half to two-thirds and width one-third to one-half that of cranidium. Glabellar furrows faint, three pairs, straight, bent posteriorly. Occipital furrow broad, shallow. Occipital ring widest at center, usually with small node. Frontal area variable. Marginal furrow shallow, gently curved. Fixed cheeks usually flat, horizontal or downsloping, width one-third or less that of glabella. Palpebral lobes short, situated on or just behind anterior one-fourth line of glabella. Palpebral furrow very faint, straight. Ocular ridge faint. Posterior limbs broadly triangular with gently convex outer margin. Posterior furrow broad, shallow. Anterior course of facial suture variable. Posterior course makes an angle of from forty-five to sixty degrees with the longitudinal axis, straight or gently curved outward.

Pygidium semicircular to subovate in outline. Axis consists of four or five segments, strongly convex transversely, bluntly rounded posteriorly, width one-third or more that of pygidium, length equal to that of pygidium minus border. Border narrow, bears three or four pairs of spines that become progressively shorter toward the axis.

PARABOLINOIDES CONTRACTUS Frederickson
Plate 59, figure 3

Parabolinoides contractus FREDERICKSON, 1949, p. 361, pl. 71, figs. 4–10.
Parabolinoides expansa NELSON, 1951, p. 776, pl. 107, figs. 1, 3.

Frontal area one-fourth to one-third length of cranidium. Brim flat. Border rounded anteriorly, convex, brim and border equal. Anterior course of facial suture strongly divergent in front of palpebral lobes, then curves inward at marginal furrow.

Remarks.—This species is distinguished from *P. hebe* by its divergent facial sutures that result in a wider, flaring brim.

Parabolinoides expansa Nelson is similar to *P. contractus* except in its downsloping brim and flat border, and the holotype occurs with *Eoorthis remnicha* at Taylors Falls. Because *P. expansa* occupies a stratigraphic position equivalent to that of *P. contractus* of central Wisconsin, it might better be considered a geographic variant of *P. contractus*.

Occurrence.—Rare in the *Eoorthis* subzone. Birkmose member: Taylors Falls (F18.1). Tomah member: Dellona (F207.1).

Figured specimen.—UM T6672.

PARABOLINOIDES HEBE Frederickson
Plate 59, figures 2, 4

Parabolinoides hebe FREDERICKSON, 1949, p. 361, pl. 70, figs. 7, 8, pl. 71, figs. 1–3.

Frontal area between one-fourth and one-third length of cranidium. Brim flat. Border obtusely pointed, convex, brim and border subequal. Anterior course of facial suture slightly divergent in front of palpebral lobes.

Occurrence.—Common in the *Eoorthis* subzone. Tomah member: Dellona (F207.1, 207.3, 207.4), Horseshoe Bluff (F179.3), Springville (F185.3).

Figured specimens.—UM T6673a, b.

PARABOLINOIDES PALATUS Berg, n. sp.
Plate 59, figures 5, 8

Frontal area one-third or more length of cranidium. Brim flat or gently convex, downsloping or horizontal. Anterior course of facial suture strongly divergent in front of palpebral lobes, then curves inward at marginal furrow.

Remarks.—This species is distinguished from all other species of *Parabolinoides* by its long frontal area and wide brim.

Occurrence.—Common in the *Parabolinoides palatus* teilzone. Birkmose member: Galesville (F76.1), Misha Mokwa (F181.1). Tomah member: Franklin (F73.2), Goodenough Hill (F52.2K), Hillsboro (F187.1), Hustler (F79.2, 79.3), Knapp (F188.1, 188.2), Lone Rock (F83.1), Maynard Pass (F78.1, 78.5), Northfield (F42.3, 42.4), Sextonville (F178.2), Tunnel City (F82.1).

Holotype.—UM T6676a, paratype UM T6676b.

Genus TAENICEPHALUS Ulrich and Resser, 1924

Taenicephalus ULRICH and RESSER in Walcott, 1924, p. 59; WALCOTT, 1925, p. 116.

Type species.—*Conocephalites shumardi* Hall, 1863.

Cranidium, excluding posterior limbs, quadrangular in outline, flat to gently convex transversely and longitudinally. Glabella quadrate, straight-sided, tapering forward, truncate anteriorly, length about one-half and width about one-third that of cranidium; anterior pits may be present. Glabellar furrows weak to moderate, anterior pair if present very faint, straight and short, two posterior pairs curving gently backward. Occipital furrow strong, straight or curving forward in middle. Occipital ring of moderate width, may have small node. Frontal area one-fourth to one-third length of cranidium. Marginal furrow straight and distinct, brim and border variable. Fixed cheeks convex, upsloping opposite palpebral lobes. Palpebral lobes short, convex, situated on anterior one-third line of glabella. Palpebral furrows incomplete, medial portion not visible. Posterior limbs of moderate width, equal to or slightly shorter than occipital ring. Posterior furrow distinct, broad. Anterior course of facial suture straight or slightly divergent. Posterior course curved, makes an angle of about forty-five degrees with longitudinal axis.

Remarks.—*Taenicephalus* is characterized by incomplete palpebral furrows, low to moderate convexity, and nearly straight dorsal and marginal furrows that tend to give the cranidium a distinctive rectangular appearance.

TAENICEPHALUS ALTUS Nelson
Plate 60, figure 10

Taenicephalus shumardi (Hall) WALCOTT (part), 1925, p. 117, pl. 17, fig. 15; SHIMER and SHROCK, 1944, p. 633, pl. 266, fig. 17.
Taenicephalus altus NELSON, 1951, p. 777, pl. 107, figs. 2, 4, 7; BELL, FENIAK, and KURTZ, 1952, p. 187, pl. 31, fig. 6.

Brim strongly convex and twice as wide as convex border, nearly one-half length of glabella. Border triangular, rounded anteriorly. Marginal furrow deep. Facial suture distinctly divergent anterior to eyes.

Remarks.—This species differs from *T. shumardi* chiefly in its wider brim. The figured specimen shows the typically rounded anterior margin of the border, not clearly illustrated by either Nelson (1951) or Bell, Feniak, and Kurtz (1952).

Occurrence.—Very common in the *Taenicephalus altus* teilzone. Tomah member: Brownsville (F209.1B, 209.3B), Dakota (F8.2K), Galesville (F76.2), Hell Hollow (F57.1B, 57.2K), La Crescent (F59.2K), Menomonie (F47.2), Misha Mokwa (F181.2), Mount Tom (F58.2K), Wheeler (F48.7). Reno member: Franklin (F73.6). Mazomanie member: Wheeler (F48.9).

Figured specimen.—UM T6679.

TAENICEPHALUS SHUMARDI (Hall)
Plate 59, figures 11–14

Conocephalites shumardi HALL, 1863, p. 154, pl. 7, figs. 1, 2, pl. 8, fig. 32.
Taenicephalus shumardi (Hall) WALCOTT, 1924, p. 59, pl. 13, fig. 1; RESSER, 1942, pl. 20, fig. 21.

Brim and border moderately convex and about equal in width; large specimens may have brim almost twice as wide as border and one-third the length of glabella. Border triangular, distinctly pointed anteriorly. Facial suture straight or slightly divergent anterior to eyes.

Remarks.—This species is variable in the strength of the dorsal and marginal furrows and in the presence or absence of anterior

pits. The variation is partly the result of preservation, but, in general, flatter cranidia with stronger furrows and distinct anterior pits are found only with *Conaspis perseus* and *Maustonia nasuta*.

Occurrence.—Very common in the *Parabolinoides palatus* and *Maustonia nasuta* teilzones. Birkmose member: Galesville (F76.1), Misha Mokwa (F181.1). Tomah member: Blair (F46.1, 46.2), Brush Creek (F180.2, 180.3), Dallas (F23.1, 23.2), Franklin (F73.2, 73.3), Goodenough Hill (F52.3K), Hillsboro (F187.2, 187.3, 187.4), Hustler (F79.4, 79.5), Knapp (F188.2), Lone Rock (F83.1, 83.3), Maynard Pass (F78.1, 78.2), Northfield (F42.5, 42.6), Panther Hill (F53.2, 53.3), Sextonville (F178.3, 178.4), Sparta (F77.1). Reno member: Franklin (F73.5), Maynard Pass (F78.3, 78.6). Mazomanie member: Cooley Hill (F81.1).

Figured specimens.—AMNH 326/1 (holotype), UM T6674, UM T6677b, UM T6678.

Prosaukia SUBZONE SPECIES

Genus DARTONASPIS Miller, 1936
DARTONASPIS KNIGHTI Miller
Plate 61, figures 5, 6, 12

Dartonaspis knighti MILLER, 1936, p. 29, pl. 8, figs. 34, 35.
Chariocephalus knighti (Miller) RESSER, 1942, p. 4.

Remarks.—This species is characterized by its quadrate glabella, wide fixed cheeks, and short posterior limbs. The short frontal area is nearly hidden in dorsal view below the anterior end of the strongly convex glabella, and this feature, together with the long palpebral lobes, distinguishes *D. knighti* from *Chariocephalus whitfieldi* Hall, with which it is associated.

Occurrence.—*Prosaukia* subzone with *Prosaukia longicornis*. Mazomanie member: Horseshoe Bluff (F179.6), Ridgeland (F32.6).

Figured specimens.—UM T6689a, b.

Genus IDAHOIA Walcott, 1924
IDAHOIA WISCONSENSIS (Owen)
Plate 61, figure 11

Crepicephalus? wisconsensis OWEN, 1852, tab. 1, fig. 13.
Idahoia wisconsensis (Owen) LOCHMAN, 1950, p. 329, pl. 46, figs. 11–13; BELL, FENIAK, and KURTZ, 1952, p. 189, pl. 37, figs. 3a–f (for complete synonymy).

Remarks.—Specimens of *I. wisconsensis* from the *Prosaukia longicornis* biofacies are not significantly different from those of the *Prosaukia misa* biofacies nor from those of the *Ptychaspis* subzone figured by Bell, Feniak, and Kurtz (1952). The specimen figured here is the first illustrated from the Mazomanie member.

Occurrence.—*Ptychaspis-Prosaukia* zone in both the Reno and Mazomanie members. *Prosaukia* subzone with *Prosaukia longicornis*. Mazomanie member: Cooley Hill (F81.3), Horseshoe Bluff (F179.6), Ridgeland (F32.6).

Figured specimen.—UM T6685.

IDAHOIA LATIFRONS (Shumard)
Plate 60, figure 11

Dikelocephalus latifrons SHUMARD, 1862, p. 101.
Conocephalites wisconsensis HALL (part), 1863, p. 164, pl. 7, fig. 40 only.
Idahoia latifrons (Shumard) RESSER, 1935, p. 35.

Remarks.—This species is distinguished from *I. hamulus* (Owen) by its longer frontal area, and although it resembles *I. wisconsensis*, it differs in the wider brim and less strongly divergent facial suture.

The holotype of *I. latifrons* has been lost, and the only illustration of Shumard's specimen is the drawing given by Hall (1863). A single cranidium in the present collection agrees with the original description, and although it does not occur in the *Prosaukia* subzone, it is presented here as the first adequate illustration of the species.

Occurrence.—*Ptychaspis granulosa* teilzone. Reno member: Minneiska (F66.2B).

Figured specimen.—UM T6693.

IDAHOIA cf. I. LATIFRONS (Shumard)
Plate 60, figure 12

Remarks.—Two specimens from the Mazomanie member are similar to *I. latifrons* in all cranidial proportions but differ from that species in their strongly convex cranidia. The steeply downsloping frontal area has a convex brim and flat border, and the occipital ring shows the presence of a long spine with a broad base.

Occurrence.—*Prosaukia* subzone with *Prosaukia longicornis*. Mazomanie member: Horseshoe Bluff (F179.4).

Figured specimen.—UM T6684.

Genus PROSAUKIA Ulrich and Resser, 1933

PROSAUKIA MISA (Hall)

Plate 61, figure 1

Dikelocephalus misa HALL, 1863, p. 144, pl. 8, fig. 15, pl. 10, figs. 4, 5.

Prosaukia misa (Hall) ULRICH and RESSER, 1933, p. 141, pl. 24, figs. 1–9; BELL, FENIAK, and KURTZ, 1952, p. 192, pl. 38, figs. 1a–d (for complete synonomy).

Prosaukia halli ULRICH and RESSER, 1933, p. 154, pl. 27, figs. 3–9.

Remarks.—*P. misa*, the type species, is characterized by its relatively long and flat frontal area with shallow marginal furrow. A typical specimen from the Reno member in southeast Minnesota, illustrated by Bell, Feniak, and Kurtz (1952), is refigured here for comparison with species from the Mazomanie member.

Occurrence.—*Prosaukia* subzone. Reno member in southeast Minnesota. Mazomanie member: Ridgeland (F32.3).

Figured specimen.—UM T6655b.

PROSAUKIA ANOMALA Ulrich and Resser

Plate 61, figure 10

Prosaukia? anomala ULRICH and RESSER, 1933, p. 167, pl. 29, figs. 1–3.

Remarks.—This species is distinguished from all other species of *Prosaukia* by its nearly square glabella and short frontal area. The marginal furrow is usually absent and is very weak and incomplete when present.

Occurrence.—*Prosaukia* subzone with *Briscoia schucherti* Ulrich and Resser and *Illaenurus truncatus* Feniak. Mazomanie member: Horseshoe Bluff (F179.7).

Figured specimen.—UM T6687.

PROSAUKIA cf. P. DUBIA Ulrich and Resser

Plate 61, figure 8

Prosaukia dubia ULRICH and RESSER, 1933, p 166, pl. 28, fig. 20.

Remarks.—The frontal area of *P. dubia* is similar to that of *P. misa*, but the species is distinguished by its strongly convex glabella, deeper dorsal furrow, and granulose surface. *P. dubia* differs from *P. tuberculata* chiefly in its longer frontal area, but specimens in the present collection, lacking frontal areas, are identified by their long occipital spines.

Occurrence.—*Prosaukia* subzone. Reno member: Hudson (F2.31N). Mazomanie member: Horseshoe Bluff (F179.4), Ridgeland (F32.6).

Figured specimen.—UM T6694.

PROSAUKIA LONGICORNIS Ulrich and Resser

Plate 61, figures 7, 9

Prosaukia longicornis ULRICH and RESSER, 1933, p. 156, pl. 27, figs. 12–21.

Remarks.—This species is distinguished from *P. misa* by its shorter frontal area, narrow brim, and convex border. Its occurrence with *Ptychaspis miniscaensis* in Mazomanie sandstone at Horseshoe Bluff indicates that *Prosaukia longicornis* occupies a stratigraphic position equivalent to that of *Prosaukia misa* of the Reno greensands.

Occurrence.—*Prosaukia* subzone. Mazomanie member: Cooley Hill (F81.3), Horseshoe Bluff (F179.4), Ridgeland (F32.6).

Figured specimens.—UM T6688, T6692.

PROSAUKIA TUBERCULATA Ulrich and Resser

Plate 61, figures 2–4

Prosaukia tuberculata ULRICH and RESSER, 1933, p. 159, pl. 28, fig. 5.

Remarks.—This species is characterized by its short frontal area with incomplete marginal furrow, strongly convex glabella, and deep dorsal furrow. The holotype illustrated by Ulrich and Resser (1933) shows these features, but the species as described by them was characterized as having a granulose surface and no occipital node. Specimens in the present collection are similar to the type in the nature of the glabella and frontal area. An occipital node is present on two specimens, and only one large specimen shows a distinctly granulose surface. Preservation in coarse sandstone may obscure the surface ornamentation on smaller specimens, but another large specimen lacks the granulose surface and has an occipital node. It seems probable that granulation and occipital node have no significance as specific characters.

Occurrence.—*Prosaukia* subzone. Reno member: Ridgeland (F32.4). Mazomanie member: Friendship Mound (F80.5), Horseshoe Bluff (F179.4), Ridgeland (F32.3, 32.5, 32.6).

Figured specimens.—UM T6686a, b, T6691.

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EXPLANATION OF PLATE 61

FIGS. *1*—*Prosaukia misa* (Hall). Cranidium, ×2, UM T6655b (Bell, Feniak, and Kurtz, 1952, pl. 38, fig. 1b), Hell Hollow (F57.1F). (p. 567)

2–4—*Prosaukia tuberculata* Ulrich and Resser. *2*, *3*, cranidia, first with occipital node, ×1, UM T6686b, a, Ridgeland (F32.6); *4*, large granulose cranidium, ×1, UM T6691, Friendship Mound (F80.5). (p. 567)

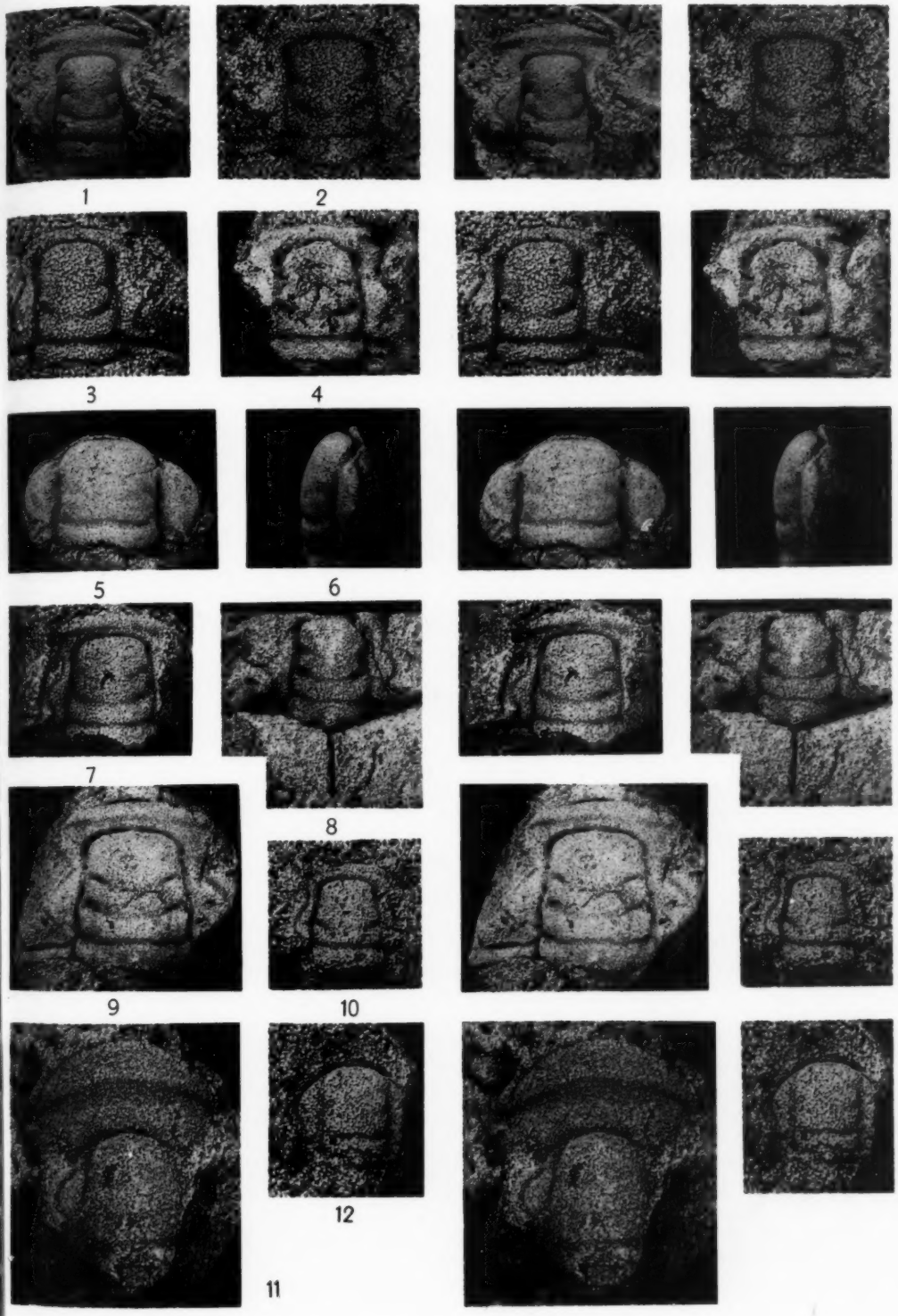
5, *6*, *12*—*Dartonaspis knighti* Miller. Dorsal and side views of large cranidium, ×1, and small cranidium, ×3, UM T6689a, b, Ridgeland (F32.6). (p. 566)

7, *9*—*Prosaukia longicornis* Ulrich and Resser. *7*, cranidium, ×2, UM T6692, Horseshoe Bluff (F179.4); *9*, cranidium, ×1, UM T6688, Ridgeland (F32.6). (p. 567)

8—*Prosaukia* cf. *P. dubia* Ulrich and Resser. Cranidium, ×1, UM T6694, Ridgeland (F32.6) (p. 567)

10—*Prosaukia anomala* Ulrich and Resser. Cranidium with marginal furrow, ×2, UM T668[illegible] Horseshoe Bluff (F179.7). (p. 56[illegible])

11—*Idahoia wisconsensis* (Owen). Cranidium, ×2, UM T6685, Ridgeland (F32.6). (p. 56[illegible])



Berg, Franconian trilobites

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BURIED OYSTER REEFS IN SOME TEXAS BAYS[1]

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ABSTRACT—Probing with poles and pipes revealed the presence of many buried oyster reefs in Aransas, Mesquite and San Antonio bays, Texas. Evidence suggests that modern reefs retain their narrow surface width at depth. Probing data are too scanty in most areas to warrant plotting the limits of individual buried reefs. Shell dredging operations have shown that such reefs are occasionally as much as 12 feet thick. The old reefs are judged to have disappeared owing to unfavorable changes in salinity.

INTRODUCTION

THIS paper is concerned with oyster reefs buried at various depths below the present bottoms in three large shallow bays on the south central Texas coast (fig. 1). All three bays are more or less cut off from the open Gulf of Mexico by low-lying barrier islands. The northernmost and largest of these bays is San Antonio, which includes two smaller connecting water bodies, Guadalupe and Hynes bays. San Antonio Bay is roughly 12 miles long in a north direction and 6 miles wide. The depth is nowhere greater than 7 feet. Mesquite Bay, farther south, is connected with San Antonio Bay by several narrow passes between low islets and exposed oyster reefs. Mesquite Bay is about 4 miles long and 3 miles wide and has a maximum depth of 4½ feet. Mesquite Bay, unlike San Antonio Bay, has a direct connection with the gulf at present through Cedar Bayou, a narrow, shallow pass. Aransas Bay, the southernmost body of water under discussion, is connected with Mesquite Bay in much the same way that Mesquite and San Antonio bays are connected. Aransas Bay is the only one of the group having a deep water connection with the open gulf. This connection is Aransas Pass, one of three major breaches in the barrier island system of south Texas. Aransas Bay is roughly 14 miles long in a northeast direction and 4 miles wide with a greatest depth of 13 feet.

Buried reefs have been detected at depths ranging from a few inches to as much as 14 feet below the bottom of the modern bays. Because data on the buried reefs were mostly obtained incidental to other work, little information is available on reef dimensions. It seems reasonable, however, to assume that buried reefs, like their modern counterparts, are mostly long and narrow in plan and do not cover broad areas. The distribution of the buried reefs apparently has no relation to the distribution of modern reefs.

The term "reef" as used in this paper refers to a narrow linear accumulation of shells, mostly those of the oyster (*Crassostrea virginica*), resulting from the successive growth of generations of oysters in the same place. Living oysters frequently, but not invariably, occupy the exposed surfaces of such reefs.

ACKNOWLEDGMENTS

The author is indebted to the various personnel of A.P.I. Project 51 who have worked with him in the field during 1951 and 1952. F. P. Shepard and other members of the Scripps Institution of Oceanography have offered many helpful suggestions and criticisms of the manuscript.

FIELD WORK

The field investigation was carried out in two parts: the first during the summer of 1951 and the second in the winter of 1952. Probing operations were carried out from the deck of a small shrimp boat with sufficiently shallow draft to allow it to reach most parts of the bays without difficulty. Two probes were used: the first, a 21 foot length of half-inch I.D. galvanized pipe

[1] This investigation was supported by a grant from the American Petroleum Institute, Project 51.

pointed at one end and marked off in one foot intervals; the second probe an ordinary 12 foot bamboo pole, similarly marked. The probes were pushed manually into the bay bottom from the boat. The penetration into the bottom was calculated by noting the depth of water and subtracting that amount from the reading on the probe at the water surface. Although distinctions between different materials encountered in probing are somewhat subjective, it is possible, in most cases, to distinguish mud, shell and sand. The bamboo probe is better adapted for detecting thin sand and shell layers than the pipe probe, but will not penetrate more than a few inches of hard sand or shell. Inasmuch as thin sand or shell layers often were found above true buried reefs, the pipe probe was used most of the time. Longer probes would have been desirable, but would probably have been too difficult to handle manually. The pipe probe was often hard to pull up from maximum penetration. Future operations of this type might be more effectively carried out with a longer probe constructed of aluminum pipe with a steel point; this would materially reduce the weight of the unit.

Selection of stations for probing was more or less haphazard during the early part of the first field season. When it was found that probing could detect many buried reefs, it was instituted as regular procedure at most stations subsequently occupied by the boat. Stations during the first field season were selected mainly to cover the

FIG. 1—Outline map of part of Texas showing location of areas investigated.

area as closely as possible and were not generally concentrated in any area. During the second field season, stations were selected to fill in gaps left by the first season's coverage, and to investigate certain areas in greater detail which were believed to be of special importance. Only three traverses were made solely for probing purposes and all three of these were located in San Antonio Bay. Two traverses were made in a north-south direction in the central part of the bay in order to discover the limits of a large reef buried about three feet below the bottom. Original data indicating the presence of this reef had been assembled from three or four east-west traverses made during the first field season. The third traverse was run across (normal to the long direction) a modern reef in order to provide some information on the lateral and vertical extent of a living shell reef. Geographic distribution of the stations and depths to which probing extended are shown in figure 2.

EXTENT OF MODERN OYSTER REEFS NEAR TEXAS COAST

Modern oyster reefs in Texas bays are usually long, relatively narrow accumulations of shell in a prevailingly soft mud bottom. The narrow, linear character of the reefs is more evident in the central parts of the bays than near the margins. Shell reefs are often less distinct near shore where loose shell and sand have been scattered over the bottom by wave action. The tendency of reefs to grow out into the bays at right angles to the shore is evident from an examination of figure 3, and has been discussed extensively by Grave (1905, p. 261) who observed such reefs in North Carolina. Most modern reefs in these Texas bays occur at depths less than 6 feet and many are partially exposed as long islands during periods of low water (fig. 4).

Shell reefs are common in central and upper San Antonio Bay, but are absent in tributary Hynes and Guadalupe bays. Lower San Antonio Bay has few reefs except where it joins Mesquite and Espiritu Santo bays and where a single long narrow reef (Panther Reef) divides this part of the bay nearly in half. This particular reef is about 5 miles long and seldom more than 150 yards wide. Closely spaced reefs and shell bottom characterize much of the area between Mesquite and Aransas bays. In Mesquite Bay proper, however, shell reefs are not abundant. Aransas Bay, on the other hand, has abundant shell reefs in its upper third, near where it joins Mesquite, St. Charles and Copano bays, but a scarcity in the lower bay.

Little information is available on the total thickness of the modern reefs in this region. The probing equipment used in this study was not satisfactory for penetrating more than a foot of ordinary shell reef. Operators of shell dredges have reported vertical thicknesses of as much as 20 feet. Some of these commercial operators, however, maintain that 20 feet is an exaggeration and that 12 feet is about the greatest thickness encountered (J. Heldenfels, personal communication). Nevertheless, Galtsoff (1941, p. 2) mentions a 20 foot thickness of some shell reefs in this area and Richards (1939, p. 1890) discusses the occurrence of shell reefs in Copano Bay at 100 feet below sea level as revealed by water well cores.

Probe traverses normal to Long Reef in Aransas Bay and Dagger Reef in San Antonio Bay suggest that reefs do not become appreciably wider with depth below the bottom. For example, probing 8 feet into the sediment 150 feet southwest of Long Reef disclosed no shell layers at all. Another probe station, about the same distance northeast of Long Reef, encountered no shell beds 9 feet below the mud surface. In San Antonio Bay, the situation is similar; Dagger Reef showed a similar lack of width at depth. One hundred and fifty feet northwest of the exposed reef a 6 foot penetration failed to find any reef material. A cross-section of Long Reef is shown in figure 5. Additional evidence for the lack of increasing width with depth is provided by a number of separate probe stations made close to exposed reefs. At least eight such probes, located within 300 feet of a reef, penetrated 8 to 14 feet of mud without striking any buried shell reefs.

BURIED REEFS

Buried reefs have been found in Aransas, Mesquite and San Antonio bays. A few probes made in Copano and Espiritu Santo bays indicated buried shell reefs there as

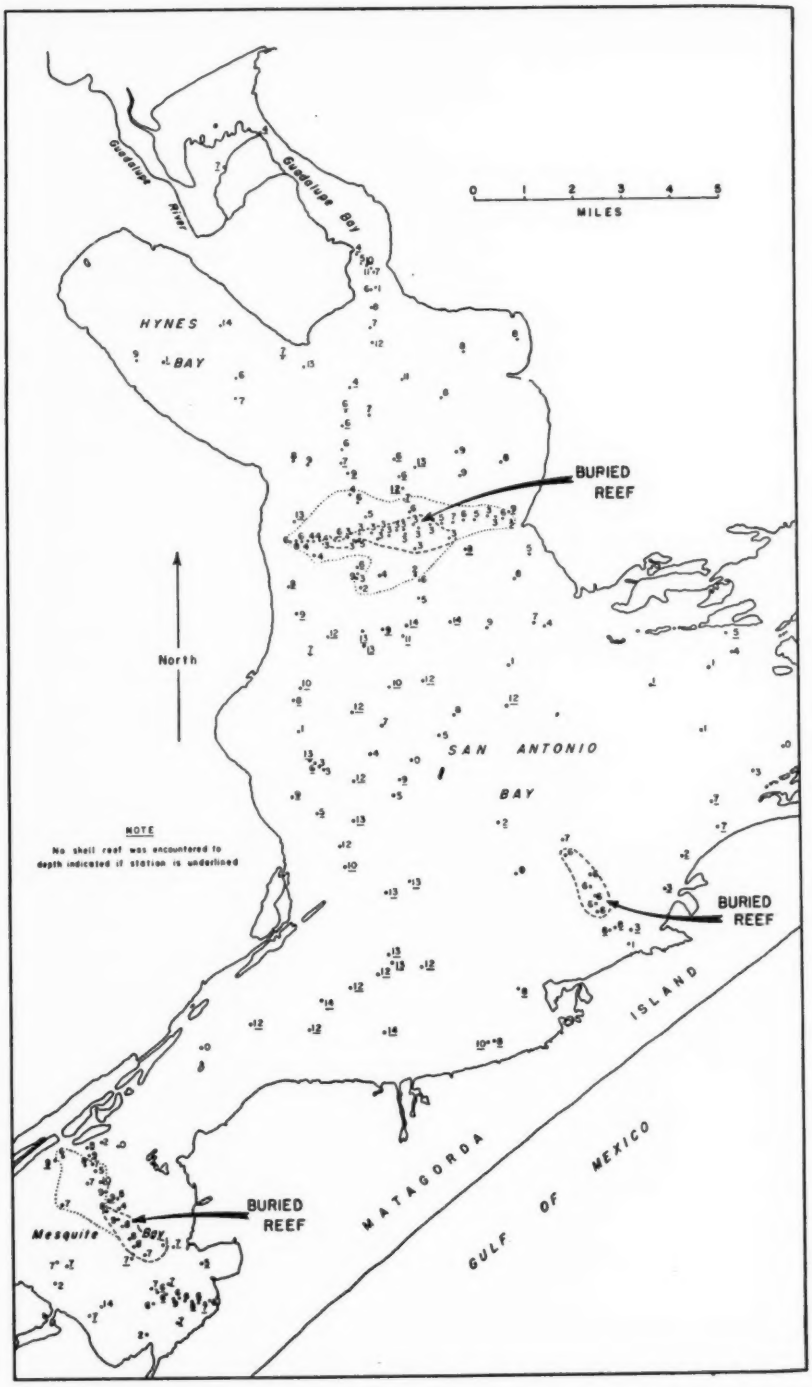

FIG. 2—Map showing the distribution of probe stations and depth of penetration in San Antonio and Mesquite bays. Dashed lines indicate probable limits of larger buried reefs.

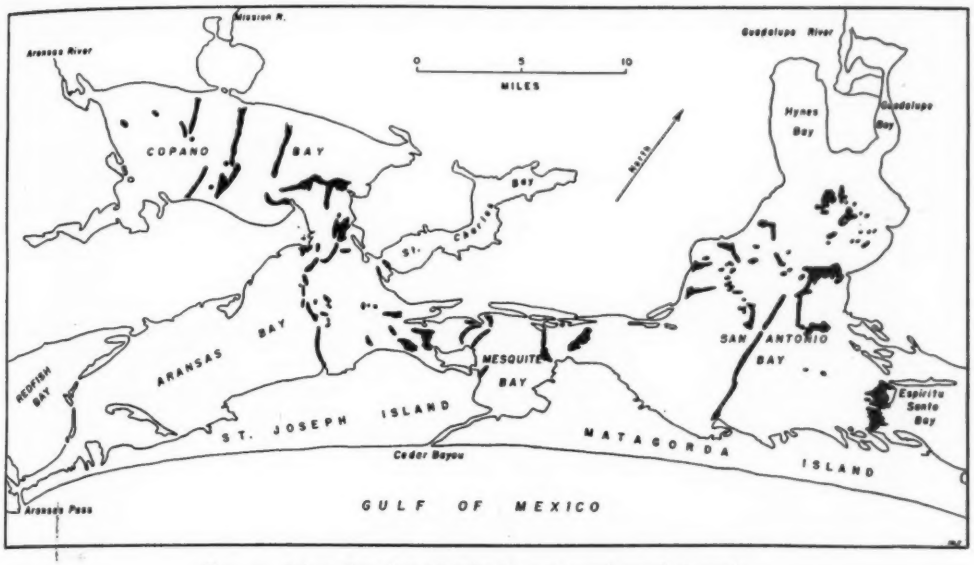

FIG. *3*—Map showing distribution of modern shell reefs.

well. Collier and Hedgpeth (1950, p. 139) report buried shell reefs from other Texas bays and it is not suggested that the occurrences described in this paper are unique. In the majority of probes, a buried reef was detected, despite the fact that many of the probes penetrated the bottom less than 5 feet. One part of the area, however, showed a surprising absence of buried reefs: southwestern San Antonio Bay. In this particular place thirteen probes were made with penetrations ranging from 8 to 14 feet and none encountered anything but soft mud. There are no modern reefs in this area. Other areas lacking modern reefs such as Hynes, Guadalupe and central Mesquite bays show evidence of buried reefs. Reefs in the first two bays may have been killed by prolonged exposure to fresh water associated with severe floods. Mesquite Bay reefs, on the other hand, may have been subjected to prolonged exposure to water of high salinity from the open gulf, or to burial by sand from the barrier islands washed into the bay during storms. Collier and Hedgpeth (1950, p. 138) point out that lowered salinities following continued heavy rains occasionally kill oysters in the inner bays. The same authors, and Galtsoff (1931, p. 9) show that high salinities have an equally disastrous effect on the oyster population. Moore (1907, pp. 61–62) cites instances where Texas reefs were nearly killed by sand washed over them by hurricanes. Once a reef community is killed, it faces eventual burial by sediment. The frequency and wide distribution of buried reefs suggests that shell reefs have been a prominent feature of the bays for some time, although their distribution shows a changing pattern.

Probing stations were not generally located close enough together to delimit buried reefs accurately. It is obvious that many linear shell reefs could easily be overlooked, even if probe stations covered the entire area on a half-mile grid. Despite this difficulty, probing seems to indicate the presence of a continuous buried reef in at least three different places in the area (fig. 2). One of these is a flat area in central San Antonio Bay underlain at a depth of from $2\frac{1}{2}$ to $3\frac{1}{2}$ feet by what appears to be a continuous reef. Possible greater extent is indicated by other probes which encountered hard shell at greater depths in this vicinity. A smaller, apparently more linear reef, occurs 6 feet below the bottom in southeastern San Antonio Bay. In Mesquite Bay, the probe was stopped many times after about 7 to 9 feet of penetration. Some of these probes, however, terminated in hard sand rather than in shell. Nevertheless, a small area in

FIG. 4—Portion of Dagger Reef, San Antonio Bay, looking southwest, during a period of low water February 29, 1952.

the central part of the bay probably is underlain by reef material at a depth of 8 to 9 feet.

CAUSE OF REEF BURIAL

Price (1947, p. 1658) expresses the opinion that burial of reefs must be attributed to sedimentation accompanying the post-glacial rise in sea-level and that it did not occur during the present stand of the gulf. F. P. Shepard (personal communication), however, by means of a study of United States Coast and Geodetic Survey charts published during the past hundred years, has found evidence that as much as one foot of sediment has been deposited in certain places in these bays during the last 60 or 70 years.

Oysters must be exposed to circulating water and do not live buried in sediment[2] or to any great extent covered by other oysters. Inasmuch as this and other investigations have shown that old shell reefs occur 14 feet or more below present bay bottoms, and the region shows no evidence of general subsidence, it follows that the bays must have been *at least 14 feet deeper* at some time in the past. This depth, based on information obtained from probing devices used in this study should be regarded as a minimum. Price (1933, pp. 924-927) points out that San Antonio Bay is a drowned river valley modified by wave action and sedimentation, and that the river excavated this former valley 50 to 75 feet or more below present sea-level. Deepening of the river channel may have been related to a general lowering of sea-level rather than to any diastrophic elevation of the land because of the common occurrence of similar estuaries along most of the Texas coast and many other coasts. The latest well-established lower sea-level occurred near the close of the Pleistocene, perhaps 23,000 years ago (Zeuner, 1945, p. 251). A possible sequence of events leading up to present conditions is therefore set forth: *first*, marine Pleistocene sediments were deposited that now crop out, among other places, along the western side of San Antonio Bay; *second*, a late Pleistocene lowering of sea-level took place accompanied by down-cutting of the river valleys across the marine Pleistocene deposits; *third*, the post-Pleistocene rise in sea-level flooded the

[2] Except in the case of long thin oysters called mud oysters found in Copano Bay and Redfish Bay, Aransas County, Texas, which may have their bases a foot below ths surface.

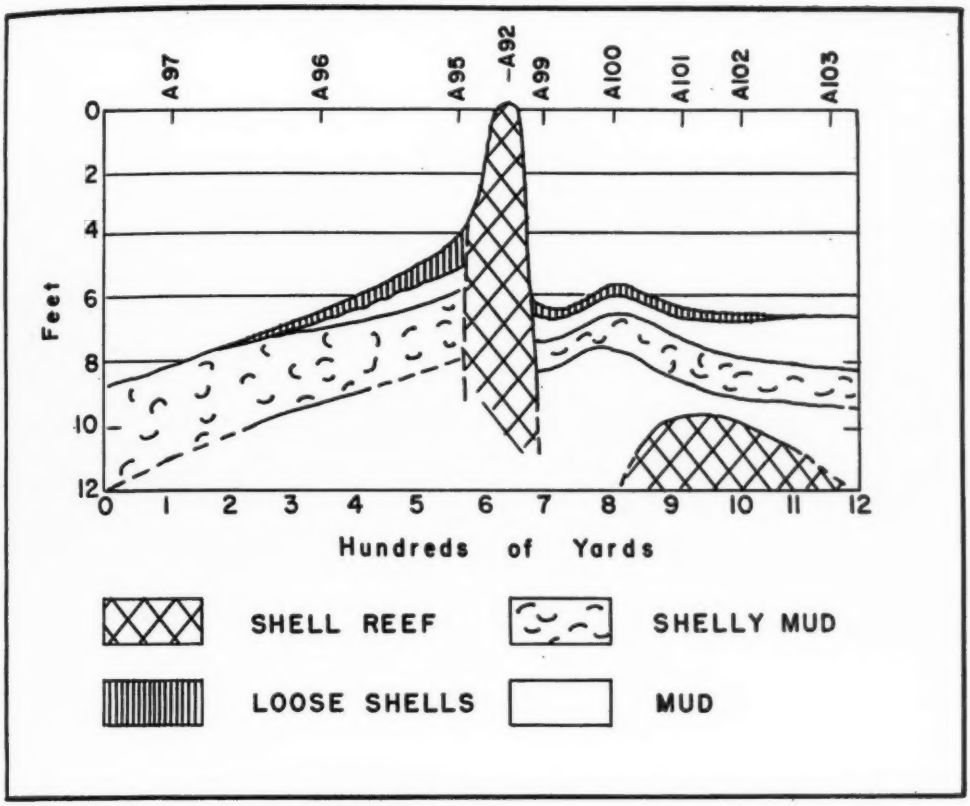

FIG. 5—Cross-section of Long Reef, Aransas Bay. Position of probe stations indicated by numbers. Vertical scale greatly exaggerated.

lower river valleys forming estuaries. These estuaries may have been subsequently widened by wave action (Price, 1933, p. 924) and may have begun to act as traps for sediment carried in by the rivers. It is probable that oyster reefs started to grow in San Antonio and Copano bays first, because the entering rivers would be expected to reduce salinities to values suitable for oyster growth. Aransas and Mesquite bays, being then open to the gulf, probably had few, if any, oyster reefs until the barrier islands formed and closed the bays off from the gulf. Probing information suggests that fewer deeply buried reefs occur in Mesquite Bay than elsewhere. *Fourth*, once the barrier island system had been developed, oyster reefs doubtless began to grow in lower Aransas and Mesquite bays.

The death and subsequent burial of oyster reefs throughout the area can be attributed to a variety of causes. In Copano and San Antonio bays an occasional prolonged influx of fresh water may have killed the reef organisms; in lower Aransas and Mesquite bays prolonged exposure to high salinity accompanying extended periods of low rainfall might have been responsible. Sand or mud deposited on reefs during unusual storms may have accounted for the death of reef-building animals on still other reefs.

CONCLUSIONS

Numerous buried shell reefs in the bays of the Rockport, Texas, area do not appear to be significantly different in size and shape from living reefs. Buried reefs have been found in areas no longer supporting reefs. This is believed to be due to either too high or too low salinities or to burial by sediments. It is believed unlikely that the buried reefs could have grown during the post-

Pleistocene rise in sea-level because of the probability that the bays would have lacked barrier islands at their mouths which in turn develop the brackish water conditions essential to oyster growth. Therefore, oyster reefs 14 feet or more below the bottom of modern bays suggest that the bays were somewhat deeper at the end of the Pleistocene and that they have since been largely filled by sediments carried in by rivers.

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NOTICE

GLOSSARY OF GEOLOGICAL TERMS

The following announcement was published in the A.G.I. *News Letter* of May, 1953.

The Glossary Committee of the A.G.I. under the chairmanship of J. V. Howell reports completion of the financing of the glossary. Under the plan, $7,500 has been allocated under a grant from the National Science Foundation, and an additional allocation, up to $7,500, has been made by the Geological Society of America. The details are now completed and work is proceeding, with the American Geological Institute as liaison agency.

Space for the housing of the project during compilation stage has been made available by the University of Tulsa in the new Petroleum Science Building, through the cooperation of A. N. Murray, head of the department of geology.

Copying of glossary entries on standard cards from glossary materials offered the Committee is proceeding. As of April 15, 1953, about 3,800 cards have been typed and a system for checking is gradually being developed.

Any readers who may know of the existence of manuscript glossaries or check lists of terms in special branches, not yet reported to the Committee, are urged to bring this information to the attention of the Chairman or the various members as soon as possible. It is the intention of the Glossary Committee to proceed rapidly with its task and have ready at least a preliminary edition by the end of 1953.

Among the members of the Glossary Committee representing organizations working with Chairman Howell are Chalmer L. Cooper, U.S.G.S., Washington, D. C., for the Paleontological Society, and Willard D. Pye, North Dakota Agricultural College, Fargo, North Dakota, for the Society of Economic Paleontologists and Mineralogists.

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OSCILLATIONS IN THE VICKSBURG STAGE AS SHOWN BY THE FORAMINIFERA FROM A WELL IN GEORGE COUNTY, MISSISSIPPI

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ABSTRACT—An oscillation chart based on the foraminiferal content of core samples from a well in southeastern Mississippi reveals several transgressions and regressions in the Vicksburg Stage, even though the section appeared at first glance to be made up of a monotonous, homogeneous foraminiferal fauna. A single chart could not be carried across the strong faunal break between the Red Bluff (lower Oligocene) and the Vicksburg Stage. By representing the two parts separately, the oscillations are more easily discerned.

Ten cubic centimeters of each sample used in this study were washed and sieved through a 150 mesh screen. A count was made of the number of specimens of every species or closely related group of species in each sample. The percentage distribution of the benthonic calcareous and arenaceous forms was calculated separately because the benthonic calcareous Foraminifera are the more delicate depth indicators. The relative depth significance of the benthonic calcareous Foraminifera was determined by plotting their percentages against the percentage of *Uvigerina* species, which are considered typically open-water elements.

The method shows promise as a correlation tool in sedimentary sections in which there were fairly rapid depth changes. An individual chart probably should not be extended over a period of time greater than an epoch because evolutionary development might tend to mask faunal changes caused by oscillations of depth.

INTRODUCTION

PALEONTOLOGISTS and stratigraphers have long been aware that one of the most commonly used methods of correlation, the upper range of fossils, or "tops" in many instances has limited value. Correlation by "tops" is usually capable of determining the time boundaries of rock units deposited through spans of time of the magnitude of geologic periods or epochs. In the younger sediments of the Gulf Coast, however, changes in faunal assemblage due to variations of ecologic factors are numerous and very rapid in units representing only small portions of an epoch and there is need for some method of time correlation other than the conventional one. For example, the checklists of Bandy (1949) and Mornhinveg and Garrett (1935) indicate that most of the "tops" occur at the top of the Vicksburgian; few are present within the unit.

One method of correlation now being tested is the oscillation chart. M. C. Israelsky (1949) suggested that if the Foraminifera could be arranged in order of their depositional depth significance, an oscillation chart might be constructed which would show relative changes in depth of water during the time of deposition of a particular stratigraphic sequence. He presented a chart based on the foraminiferal content of shaker samples ranging from 6,000 to 11,760 feet from a well in the Lirette Field, Terrebonne Parish, Louisiana. The oscillations in faunal groups of the "Miocene" were strikingly revealed.

The present study was based on Foraminifera found in core samples of the Vicksburg Stage taken from the United Gas Public Service Company well, Luce Packing Company No. 1, in Sec. 25, T. 1 S., R. 6 W., George County, Mississippi. The location of the well and other pertinent information are shown on the index map (fig. 1). An oscillation chart has been constructed and interpreted in the light of our present knowledge of: (1) the various ecologic factors controlling the distribution of the Foraminifera; and (2) Gulf Coast Oligocene history.

The deposition of large amounts of sediments during the early Tertiary required isostatic adjustments which resulted in large structural upwarps (Murray, 1947, p. 1829), These large upwarps and associated smaller

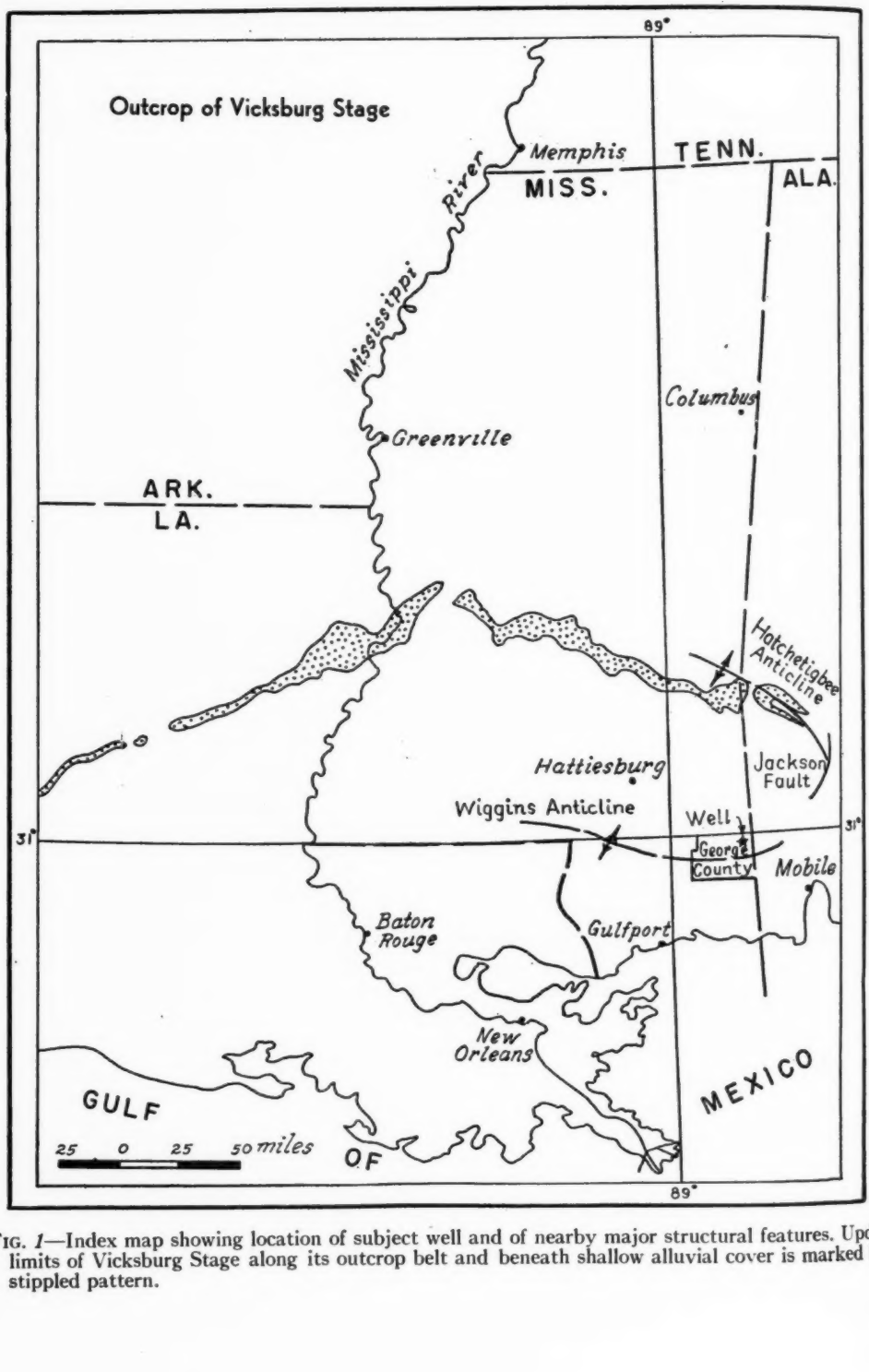

FIG. 1—Index map showing location of subject well and of nearby major structural features. Updip limits of Vicksburg Stage along its outcrop belt and beneath shallow alluvial cover is marked by stippled pattern.

uplifts strongly affected the amount and character of the nearby sediments. The axis of one of these structures, the Wiggins Anticline, passes only a few miles south of the well examined for this study. According to Murray (1947, p. 1840), the Oligocene sediments, which maintain a fairly uniform thickness over most of southern Mississippi, appear to be locally absent in the vicinity of the Wiggins Anticline. Therefore, the interpretation of sections in this area must be tempered by considering the possible effect of the upwarp on the character of the sediments found in this well.

The lithologic classification of the Oligocene by F. Stearns MacNeil (1944) is followed in this paper. Time-rock divisions proposed by Murray and Wilbert (1950) and by Murray (1952) are also utilized.

The classification utilized is:

Miocene	Catahoula sandstone—Paynes Hammock sand
Upper Oligocene	Chickasawhay limestone—Flint River formation
Disconformity	
Middle Oligocene	Vicksburg Stage
	Byram formation
	Bucatunna clay member—fossiliferous calcareous clay, dark lignitic clay, laminated fine sand and clay, laminated argillaceous fine sand with some beds of coarser sand, bentonite, and, in places, a streak of very fossiliferous marl at the top. Many barren zones.
	Marl member—difficult to define lithologically because of numerous facies but is mainly a glauconitic marl.
	Glendon limestone member—crystalline limestone.
	Marianna limestone
	Limestone member—homogeneous white or cream colored, "chimney rock."
	Mint Springs marl member—calcareous, fossiliferous, argillaceous, glauconitic sand.
Disconformity	
Lower Oligocene	Forest Hill sand—Red Bluff clay.

The thickness of the Vicksburg Stage at its type locality is given by Mornhinveg and Garrett (1935) as ranging from 105 feet to 125 feet. The thickness of the Vicksburg Stage in this well is about 90 feet.

The writer wishes to express his deep appreciation to Mr. M. C. Israelsky of the U. S. Geological Survey for the suggestion of the problem and the provision of the cores and advice; to Mr. N. C. McGowen of the Union Producing Company for permission to use the cores and well logs; to Mr. C. L. Moody, who kindly read the manuscript and offered many worthwhile suggestions; and to Miss Ellen Powelson for the drafting of the illustrations.

METHOD OF CHART CONSTRUCTION

The core intervals vary between 15 and 27 feet; most are 20 feet in length. One foot samples were taken at the well by the United Gas Public Service Company from the top, middle, and bottom of each interval. About half of each sample was available for study by the author. Four samples are missing but their loss fortunately does not seem to have appreciably disrupted the general trends shown. Sample 1867–82 (bottom) in the Red Bluff, though very fossiliferous, was not picked because the fauna was poorly preserved and difficult to record. The lithologic descriptions (table 1) are for the most part taken directly from the original log with some additions from examination of the washed samples.

Ten cubic centimeters of each sample were washed and then sieved through 150 mesh screen. A full count was considered to have been made when every specimen in the sample was preserved well enough to be identified. In a few samples some of the specimens were too badly broken or their character too much destroyed by glauconite replacement to be identified. The replacement did not appear selective. Therefore, the percentages should be approximately correct even though not every specimen could be counted. Several samples contained such large numbers of Foraminifera that it was necessary to divide the washings in an Otto microsplit in order to get an amount of material that could be counted in a reasonable length of time. A count was made of the number of specimens of each species or closely related group of species in each sample. The benthonic and pelagic assemblages were separated and their relative percent-

TABLE 1.—LITHOLOGIC DESCRIPTION OF THE CORE

	VICKSBURG STAGE
1754–74 Top	Quartz sand, dark-brown and gray, soft, friable, coarse-grained. Slightly lignitic and glauconitic. A few grains of garnet, zircon, and tourmaline.
1754–74 Bottom	Shale, brownish-black, waxy, tough, non-calcareous, slightly arenaceous. Slightly pyritiferous. A few poorly preserved Foraminifera.
1774–91 Top	Shale, dark-brown, medium-hard, slightly calcareous, pyritiferous, arenaceous, lignitic. A few grains of glauconite.
1774–91 Middle (1)[1]	Same as 1754–74 (bottom) plus streaks of brown sand. Some pyrite molds, lignitic, bentonitic (?), shell fragments.
1774–91 Bottom (2)	Same as above, a few Bryozoa fragments.
1791–1818 Top	Same as above. (Sample missing.)
1791–1818 Middle (3)	Same as above. Abundant megafossil fragments.
1791–1818 Bottom	Same as above but no quartz. Considerable pyrite and shell fragments. Hard glauconitic shell lime at base of core, bentonitic (?), barren.
1818–27 Top (4)	Shale, dark greenish-gray, calcareous, pyritiferous. Wash sample consisted of almost 100% of Foraminifera and shell fragments, bentonitic.
1818–27 Bottom (5)	Same as above. Also lignitic, bentonitic.
1827–47 Top	Same as above. (Sample missing.)
1827–47 Middle (6)	Same as above. Slightly arenaceous, no pyrite or lignite, bentonitic, ostracodes.
1827–47 Bottom (7)	Same as above. Bentonitic, ostracodes.
1847–67 Top (8)	Same as above. Bentonitic (7), highly pyritiferous, ostracodes.
1847–67 Middle (9)	Same as above. Slightly glauconitic, bentonitic, ostracodes.
	RED BLUFF CLAY
1847–67 Bottom (10)	Limestone, light speckled-gray, medium-hard, highly glauconitic. Very difficult to obtain a clean sample. Many of the Foraminifera are replaced by glauconite and others are recrystallized or broken, but there are still numerous beautifully preserved specimens. Ostracodes.
1867–82 Top (11)	Same as above.
1867–82 Middle (12)	Marl, white, medium-soft. Abundant bryozoans. Fossils much better preserved than above. Ostracodes.
1867–82 Bottom	Same as above (not picked).
1882–1902 Top (13)	Clay marl, light tan, soft, fine-grained. Bryozoans. Foraminifera well preserved.

[1] Numbers in the parentheses refer to the picked samples.

ages are shown at the far right of the chart. Next, the benthonic calcareous and arenaceous forms were separated and graphed separately, because the benthonic calcareous Foraminifera are considered the more delicate depth indicators, and because the occurrence of arenaceous types seem to be controlled somewhat by factors different from those which control the benthonic calcareous forms.

For purposes of charting, species or groups of species amounting to less than 1 per cent were eliminated and recalculations made for the remainder. To determine the relative depth significance of calcareous benthonic species, the recalculated percentages were plotted against the percentage of *Uvigerina* species which are considered to be typically deeper open-water elements. The species (or groups of species) are numbered in order of their apparent peak percentage sequence from shallower to deeper water (table 2).

The calcareous species are somewhat arbitrarily grouped to show the oscillations more readily. Each group consists of species which peak fairly close together and which show similar changes in distribution with oscillations in depth. The group boundaries are outlined by the heavy black line in figure 2. As the species and group numbers move to the left, deepening is indicated.

At first the whole section was plotted as one unit. However, it was found that there was such a marked difference between the assemblages of the lower marl and those of the upper clays that the resulting chart was highly confused. When the two groups were charted separately, the oscillations in each were clearly shown. This separation may represent a fairly significant time break.

TABLE 2.—SAMPLES ARRANGED IN ORDER OF DEPTH

% *Uvigerina*	Sample No.	Depth in Well	Peaks	
			Calcareous	Arenaceous
			VICKSBURG STAGE	
0.0	8	1847–67 Top	1. *Guttulina* spp.	1. *Textularia* sp. D. 2. *Textularia subhauerii* 3. *Textularia* sp.?
1.0	4	1818–27 Top	2. *Cibicides americanus* var. 3. *Bitubulogenerina aperta* 4. *Bitubulogenerina vicksburgensis*	4. *Spiroplectammina mississippiensis*
1.6	5	1818–27 Bottom	5. *Cibicides americanus* 6. *Cibicides* spp. 7. *Bolivina* spp. 8. *Discorbis* 9. *Nonionella* spp. 10. *Quinqueloculina* spp. 11. *Reussella rectimargo hebetata*	5. *Textularia tumidula*
6.6	6	1827–47 Middle	No peaks	No peaks
8.6	7	1827–47 Bottom	12. *Angulogerina byramensis* 13. *Quinqueloculina bicostata*	6. *Textularia tumidula* var. 7. *Textularia* sp. B.
15.1	3	1791–1818 Middle	14. *Cibicidina mississippiensis* 15. *Siphonina advena* 16. *Eponides* spp. 17. *Cibicides vicksburgensis*	No peaks
31.9	9	1847–67 Middle	18. *Robulus* sp. 19. *Cibicides pseudoungerianus* 20. *Anomalina bilateralis* 21. *Cassidulina crassa* 22. *Uvigerina* spp.	8. *Textularia* sp. C.
			RED BLUFF—JACKSON STAGE	
1.6	10	1847–67 Bottom	1. *Robulus* spp. 2. *Siphonina advena* 3. *Bolivina byramensis* 4. *Bolivina mexicana* 5. *Cibicides americanus* 6. *Cibicides* spp. 7. *Eponides* (?) 8. *Angulogerina byramensis*	No peaks
3.1	11	1867–82 Top	9. *Bolivina* spp. 10. *Cibicides pseudoungerianus* var. 11. *Siphonina danvillensis* 12. *Anomalina* spp. 13. *Reussella rectimargo hebetata*	1. *Spiroplectammina mississippiensis*
8.6	12	1867–82 Middle	14. *Reussella rectimargo* 15. *Cibicides cocoaensis*	2. *Spiroplectammina latior* 3. *Textularia* sp. 4. *Textularia distincta* 5. *Textularia* aff. *T. claibornensis*

TABLE 2.—(*continued*)

% *Uvigerina*	Sample No.	Depth in Well	Peaks	
			Calcareous	Arenaceous
		RED BLUFF—JACKSON STAGE		
15.9	13	1882–1902 Top	16. *Cibicidina mississippiensis* 17. *Cibicides pippeni* 18. *Cibicides lobatus* 19. *Nonion micrum* 20. *Anomalina bilateralis* 21. *Discorbis* spp. 22. *Dentalina* spp. 23. *Gyroidina* sp. A. 24. *Cibicidina mauricensis* 25. *Cibicides* aff. *C. tallahatensis* 26. *Angulogerina danvillensis* 27. *Uvigerina* spp.	6. *Spiroplectammina alabamensis diminutiva*

A separate plot of the arenaceous forms was made for purposes of comparison. However, they were not grouped because only a few species were present.

Specimen counts of the calcareous and arenaceous benthonic species are listed along the left margin of the respective columns. Split samples were recalculated back to the original 10 cubic centimeter volume. Samples 1 and 2 were not charted because the preservation was so poor that an accurate count was impossible.

Species identifications for the most part are based on Bandy's paper (1949).

INTERPRETATION OF THE CHART

Figure 2 shows that in addition to the faunal breaks there is a very pronounced deepening between samples 10 and 9. The deepest point in the section sampled is sample 9. It probably can be correlated with the transgression of the Marianna limestone (MacNeil, 1944, p. 1328). The Red Bluff in this well correlates very well faunally and lithologically with the same formation at Little Stave Creek, Alabama (MacNeil, 1944, p. 1322; Bandy, 1949). This break seems, therefore, to be an excellent time line and might serve as a good base line for comparing the oscillations with those in other wells. Samples 10, 11, 12, and 13 show a very regular deepening through the Red Bluff and into the Jacksonian.

Within the Vicksburg Stage, the deepening in sample 9 is followed by shallowing in sample 8, moderate deepening in sample 7, gradual shallowing through samples 6, 5, and 4, another fairly strong deepening in sample 3, and finally, probable shallowing through samples 2 and 1.

It is difficult to divide the Vicksburgian here into its smaller units by comparison with outcrop descriptions because of the downdip changes. One might tentatively place the lower limit of the Bucatunna clay at about 1827 feet using lignite as a marker. It is possible that the deepening in sample 7 might be correlated in time with the Glendon limestone. No attempt here is made to divide the Vicksburgian except to suggest the possibilities mentioned just above.

The sand lying above the Vicksburgian at approximately 1760 feet is the Catahoula or Paynes Hammock sand of lower Miocene age.

A comparison of the Red Bluff with the Vicksburgian suggests that the latter, excluding sample 9, was deposited at relatively shallower depths than was the Red Bluff. *Robulus* spp. and *Siphonina advena*, for example, are in group I of the Red Bluff, but are in groups IV and III, respectively, of the Vicksburgian. Species common to the two sections do not maintain the same relative positions in each section, but, except for *Siphonina advena*, they are all small in percentage or irregular in distribution. It is of interest to note that the conventional interpretation of the relations along the outcrop belt is that the Red Bluff is a shallower

water deposit than the Vicksburgian limestones (personal communication, G. E. Murray, July 2, 1952). The upper portion of the Red Bluff in this well is marl and contains bryozoan fragments. This indicates clear water conditions and suggests the possibility that the control is not entirely due to depth, but may also be a function of the type of bottom and the clarity of the water. The difference in fauna between the two formations could be partly evolutionary and partly environmental.

The section reveals that no species characteristic of brackish water and only a small percentage of species from near shore zones are represented. Comparison of the section with recent profiles (Lowman, 1947; Parker, 1948) suggests that the shallowest depth of the Vicksburgian at this location was about 90 to 100 meters. As faunal zones are less distinct and have broader ranges in deeper waters, it is to be expected that oscillations at these points would be more difficult to perceive. That oscillations can be detected in a section which, upon spot checking or even checklisting appears to present a monotonous, stable fauna is perhaps the most encouraging result of this study.

The oscillations in the arenaceous column correspond qualitatively with those indicated by the calcareous column. The percentage distribution of the pelagic forms is roughly related to the oscillations in the calcareous column. Higher percentages of *Globigerina* are present in the deeper water samples than in those representing shallower water.

GENERAL COMMENTS ON THE USE OF THE CHART

The great advantage of the chart lies in its relativity. A well located up dip may contain faunas representative of much shallower water than one farther down dip. Attempts to correlate the two wells using "tops" and lithology might be difficult because the sections would be very different. However, each would record the same transgressions and regressions. If the two columns are matched using the same time line as a base, the correlations can be easily made.

The method would be of great use for locating time horizons in an oil field, especially where the section consists of thick shale, marl, or limestone sequences. If one well is completely plotted, an experienced worker could conceivably use the one chart and make his correlations without having to make any but a qualitative study of the other wells. After the main deep points and shallow points in the detailed section have been determined and the faunal assemblages have been thoroughly studied, it is possible that corresponding points in the other wells may be located merely by inspection. As correlations are made over greater distances, more wells will have to be plotted in detail. Care must be used in areas in which local differential upwarping and downwarping occurred contemporaneously with deposition. Later faulting will also cause difficulties of interpretation.

One disadvantage of the method lies in the time required to pick, count, identify, and plot up a section. Even if a good check list is available, considerable time must be spent trying to identify every specimen, many of which may be poorly preserved. Naturally, the more familiar the micropaleontologist is with an area, the faster the work will proceed. One solution to this problem might be to count fewer species, say only those making up 10 per cent or more of a sample. It may even be possible to use only three or four dominant, depth-sensitive species and still be able to chart the oscillations.

CONCLUSIONS

The study of oscillations in a section through the Vicksburg Stage produced two significant results:

1. Though the section appeared at first glance to be made up of a rather monotonous, homogeneous foraminiferal fauna, a plot of the percentage distributions of species and species groups nevertheless recorded very distinct oscillations.

2. A single chart could not be carried across a strong faunal break such as occurs between the Red Bluff and the Vicksburgian. By making separate charts above and below this time line a clear picture of the oscillations was resolved.

The author feels that the oscillation chart method will prove to be a very worthy correlation tool in sedimentary sections in

which there were fairly rapid depth changes. Unfortunately, only a few charts have been constructed and no comparison of sections has been made. Further experimentation is definitely desirable and warranted.

Wells within a local area such as an oil field should be expected to correlate perfectly down to the smallest changes, except where complicated by faulting. Regionally, there will be minor differences due to differential movements contemporaneous with deposition, but the larger transgressions and regressions might still be correlated.

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NOTICE

TEXAS HIGHWAY GEOLOGIC STRIP MAPS

The Houston Geological Society has released the first in a series of Geologic Strip Maps of Texas highways. This initial map covers parts of highways 75 and 77 from Galveston through Houston, Conroe, Corsicana, Dallas, and Denton, to the Texas-Oklahoma state line.

The maps are prepared by the Highway Strip Map Committee of the Houston Geological Society, under the direction of F. W. Rolshausen, chairman, and are intended to reveal to the traveller the names of the geologic formations he is crossing, the oil fields he passes, and other information of interest along the way. They cover an area of about 4 miles on each side of the highways.

In detail, this first map shows location of formation contacts, approximate position of faults, subsurface contours, type localities, and good outcrops along the way, and a complete geologic column of Texas. Also shown are data for each county, including climatic factors, area, elevation, history, population, and smaller individual county maps showing oil-field locations. Locations of radio stations, drive-in theaters, motels, cafes, and monuments are likewise shown.

The Houston Geological Society, in cooperation with other Texas societies, is preparing further maps along other highways over the state; it is hoped that the maps will be so interesting and useful to geologists and to the general travelling public that other states will undertake similar projects.

Copies of the map may be ordered from Frank J. Gardner, Secretary, Houston Geological Society, Box 331, Houston, Texas. Price, $1.50 per copy.

JACKSON STAGE—RED BLUFF CLAY — VICKSBURG STAGE — CATAHOULA—PAYNES

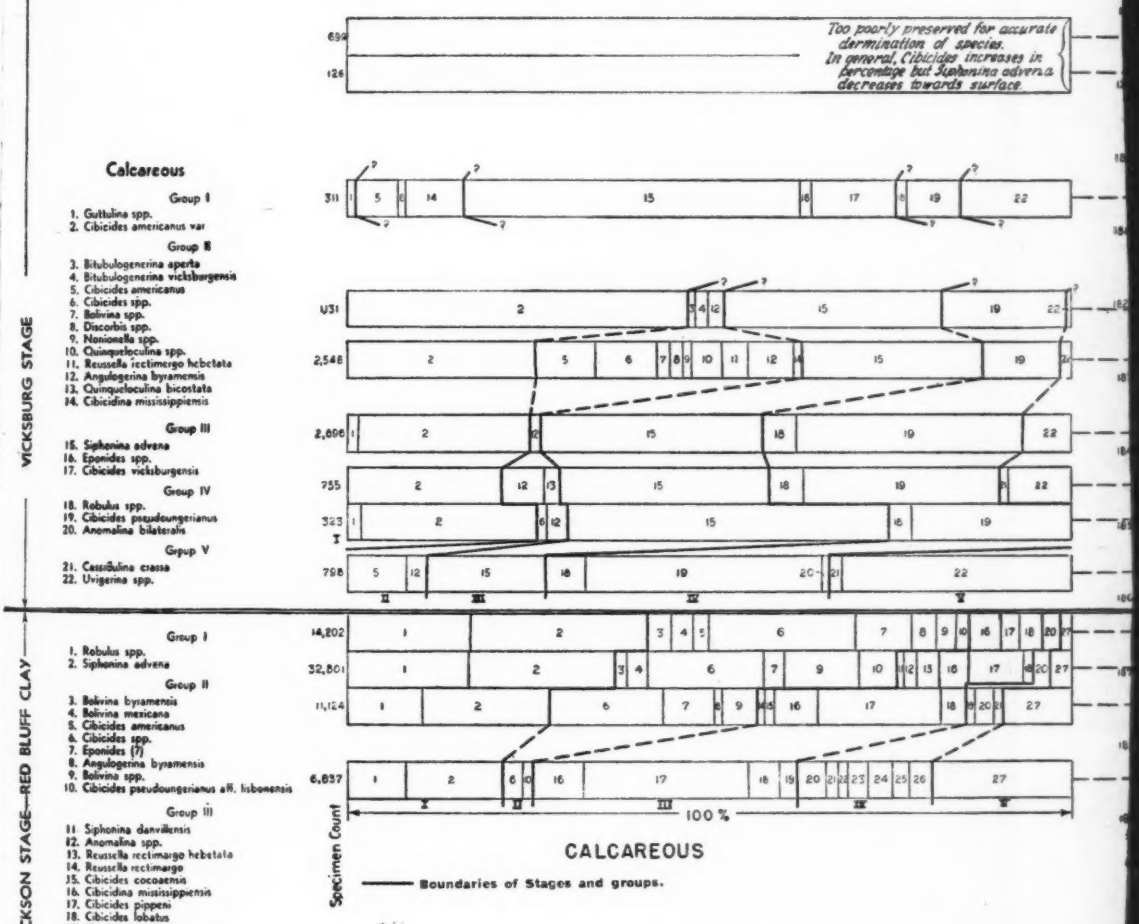

FIG. 2—Benthonic oscillation chart. Base
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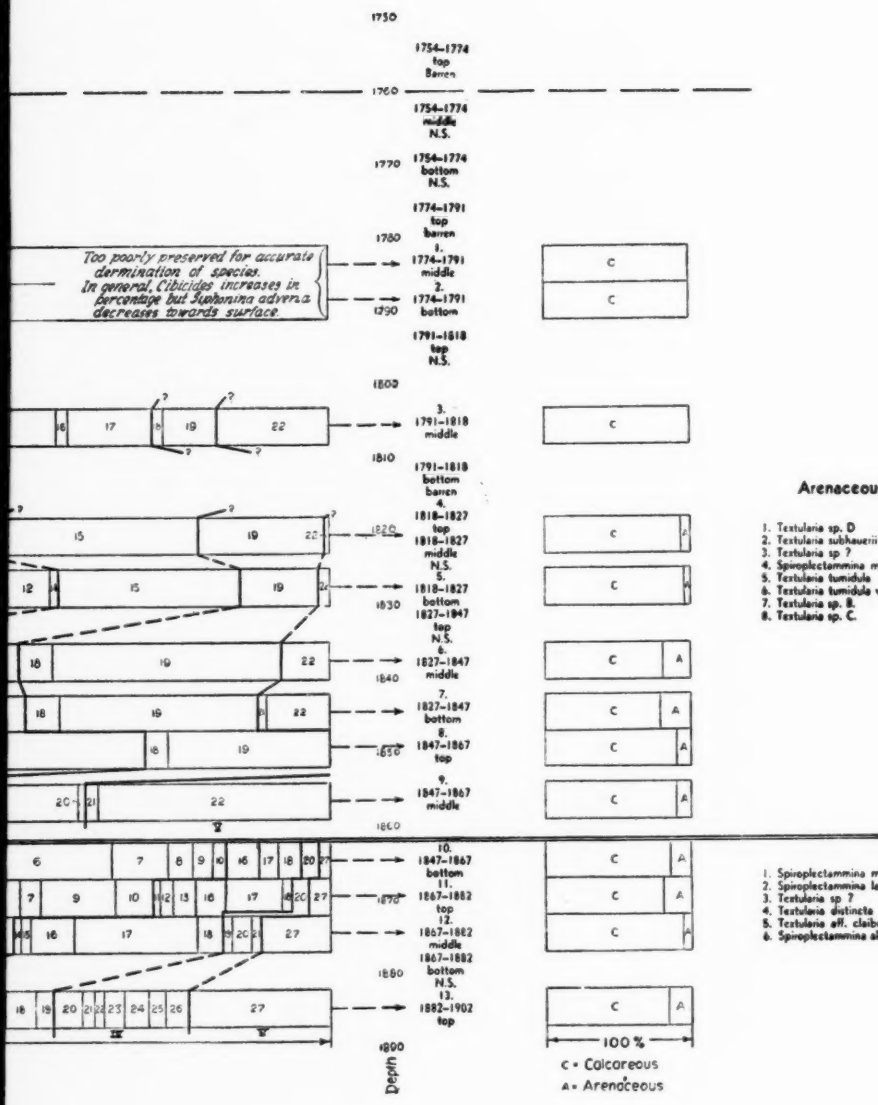

G. 2—Benthonic oscillation chart. Based on Foraminifera in United Gas Public Service C
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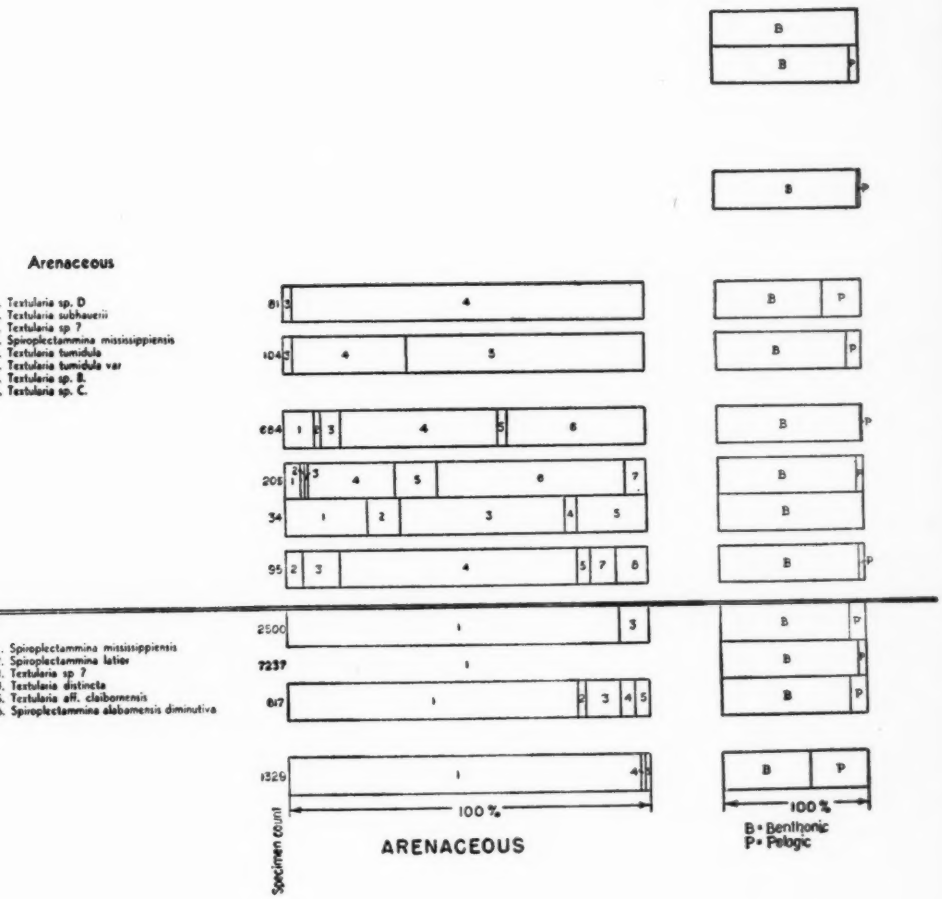

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JOURNAL OF PALEONTOLOGY, VOL. 27, NO. 4, PP. 585–595, 8 TEXT FIGS., JULY 1953

EVOLUTION IN BASAL PLATES OF MONOCYCLIC CAMERATE CRINOIDS

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ABSTRACT—The authors believe that the most primitive of the pentagonal-based Monobathrida (Glyptocrinidae) descended from a pre-Cincinnatian tanaocrinoid through upward elimination of the anal plate from the radial circlet accompanied by decrease in the size of the posterior basal. The development of the unequally quadripartite and tripartite bases in the pentagonal-based Monobathrida was accomplished by simple anchylosis of sutures.

The development of the various arrangements of basal plates of hexagonal-based Monobathrida we believe to be the result of anchylosis accompanied by atrophy and compensating hypertrophy of basals.

Plate reduction or elimination of a basal plate could be the result of (1) absorption by ameboid cells, (2) failure to develop as a result of deep-seated atrophy, or (3) inhibition of growth as a result of accelerated growth of adjacent plates.

INTRODUCTION

NTIL 1943 when R. C. Moore and L. R. Laudon published their "Evolution d Classification of Paleozoic Crinoids," st of the workers who had studied crinoid olution assumed that camerates in which e anal plate lies within the radial circlet re derived from those in which it lies ove the radials.

Moore and Laudon believe, however, that universal and evolutionary trend in the e history of Paleozoic crinoid stocks is e upward displacement and ultimate mination from the dorsal cup of all plates cept the radials and the one or two circlets plates below them" (Moore and Laudon, 43, p. 20), and that accordingly camerates which the anal plate has been displaced ward are more advanced than those in ich it separates the posterior radials. Since the character of the base of camerates varies according to the position of the al plate within or above the radial circlet, discussions published prior to 1943 of the olution of the crinoid order now known Monobathrida (monocyclic camerate noids, Moore, Lalicker and Fischer, 1952, 634) have been based on the assumption at hexagonal-based Monobathrida (i.e., ose in which the anal plate lies within the dial circlet) descended from those with a ntagonal base.

No known article on this subject has appeared since the publication of the Moore and Laudon paper, although if the concepts of crinoid evolution advanced by Moore and Laudon are valid, radical changes are necessitated in the ideas previously held concerning evolutionary trends in the structure of the basal circlet of monocyclic camerate crinoids.

Moore and Laudon (1943) do not consider in much detail the derivation of the various modifications of base structure and plate arrangement in the Monobathrida, although their discussion of the evolution of the families of this order, based on changes in various features of cup shape and structure, suggests an evolutionary sequence of changes in the basal circlet.

It is the purpose of this paper (1) to demonstrate possible evolutionary trends in the bases of monocyclic camerate crinoids in harmony with the Moore and Laudon (1943) concept of crinoid evolution, and (2) to suggest how these changes in base structure and plate arrangement might have been accomplished.

GENERAL REVIEW OF BASE STRUCTURE IN CRINOIDS

The basal cycle (in monocyclic forms) and infrabasal cycle (in dicyclic forms) in crinoids are usually composed of five plates. However, there are numerous exceptions to this pattern.

The Flexibilia, entirely dicyclic, have only three infrabasals, two more or less equal in

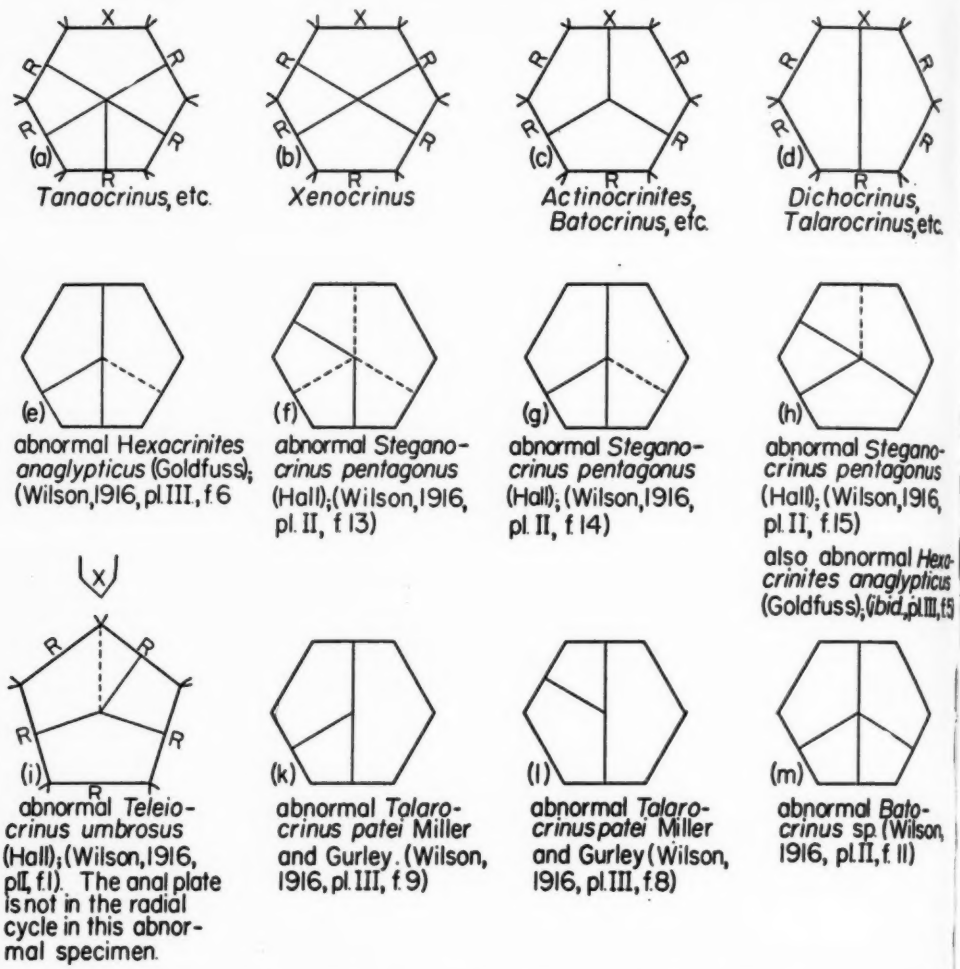

X
R
(a)
Tanaocrinus, etc.
(b)
Xenocrinus
(c)
Actinocrinites, Batocrinus, etc.
(d)
Dichocrinus, Talarocrinus, etc.
(e)
abnormal Hexacrinites anaglypticus (Goldfuss); (Wilson, 1916, pl. III, f. 6
(f)
abnormal Steganocrinus pentagonus (Hall); (Wilson, 1916, pl. II, f. 13)
(g)
abnormal Steganocrinus pentagonus (Hall); (Wilson, 1916, pl. II, f. 14)
(h)
abnormal Steganocrinus pentagonus (Hall); (Wilson, 1916, pl. II, f. 15)
also abnormal Hexacrinites anaglypticus (Goldfuss), (ibid., pl. III, f. 5)
(i)
abnormal Teleiocrinus umbrosus (Hall); (Wilson, 1916, pl. I, f. 1). The anal plate is not in the radial cycle in this abnormal specimen.
(k)
abnormal Talarocrinus patei Miller and Gurley. (Wilson, 1916, pl. III, f. 9)
(l)
abnormal Talarocrinus patei Miller and Gurley (Wilson, 1916, pl. III, f. 8)
(m)
abnormal Batocrinus sp. (Wilson, 1916, pl. II, f. 11)

FIG. 1—Diagrams illustrating various basal plate arrangements described for hexagonal-based monocyclic camerate crinoids. Dotted lines in diagrams of abnormal specimens show normal position of sutures.

size, and one about half as large lying in a right posterior position.

Most monocyclic Inadunata have five basals, although some show a reduction of the number of plates in this circlet. Some dicyclic Inadunata likewise show a reduction of the infrabasal plates to three, or more rarely, to one.

Dicyclic Camerata (Diplobathrida) show no variation from the pattern of five basals and five infrabasals. Monocyclic Camerata (Monobathrida), however, show interesting variations in the structure of the basal circlet. Basal plates in this group occur in fives, fours, threes, twos, and occasionally as a single plate. In general, basal plates in monocyclic camerate crinoids show a progressive reduction in number stratigraphically upward.

The position and relative size of the basal plates of monocyclic camerates in which the anal plate lies within the radial circlet differ from those in which the radials are all in contact and the anal plate lies above the radial circlet.

In camerates in which the anal plate is included in the radial circlet the base is more or less hexagonal. The variations in the

number and arrangement of basal plates which have been described for crinoids of this type are shown in figure 1.

Camerates in which the anal plate lies above the radial circlet have pentagonal bases. The variations in number and arrangement of basal plates described for crinoids of this type are shown in figure 2.

OUTLINE OF PREVIOUSLY DEVELOPED THEORIES CONCERNING THE EVOLUTION OF THE BASAL CIRCLET OF THE MONOBATHRIDA

In their excellent monograph "The North American Crinoidea Camerata," Charles Wachsmuth and Frank Springer (1897) published their views concerning the manner in which modifications of the basal circlet of monocyclic camerates were effected. With the exception of an earlier paper by Beyrich (1871), this discussion of evolutionary development of the basal plates of crinoids was the first general treatment of the problem.

The pattern of evolution developed by Wachsmuth and Springer was founded on the concept that pentagonal-based monocyclic camerates were ancestral to forms with a hexagonal base. They believed that the introduction of an anal plate into the radial circlet widened the cup and truncated the posterior basal. As a result the posterior basal became enlarged so that the interradial position of the basals was maintained. This widening was accomplished, Wachsmuth and Springer suggested, by the addition of an x segment as shown in figure 3.

Wachsmuth and Springer derived the hexagonal, bipartite base from the tripartite by a shifting of sutures in which the x segment is combined with plate de and plate c with ab (fig. 3f). Wilson (1916, p. 670) voices what seems to be a valid objection to this explanation because it involves improbable "shifting back" of a suture.

The interesting and comprehensive treatment of monocyclic camerate bases by Wilson (1916) is diagrammed in figure 4. Wilson believed this evolution was accomplished principally as the result of three factors:

(1) The interpolation of an anal plate into the radial circlet, resulting in an enlargement of the posterior basal. This enlargement was symmetrical. Thus, like Wachsmuth and Springer, he derives the primitive, hexagonal-

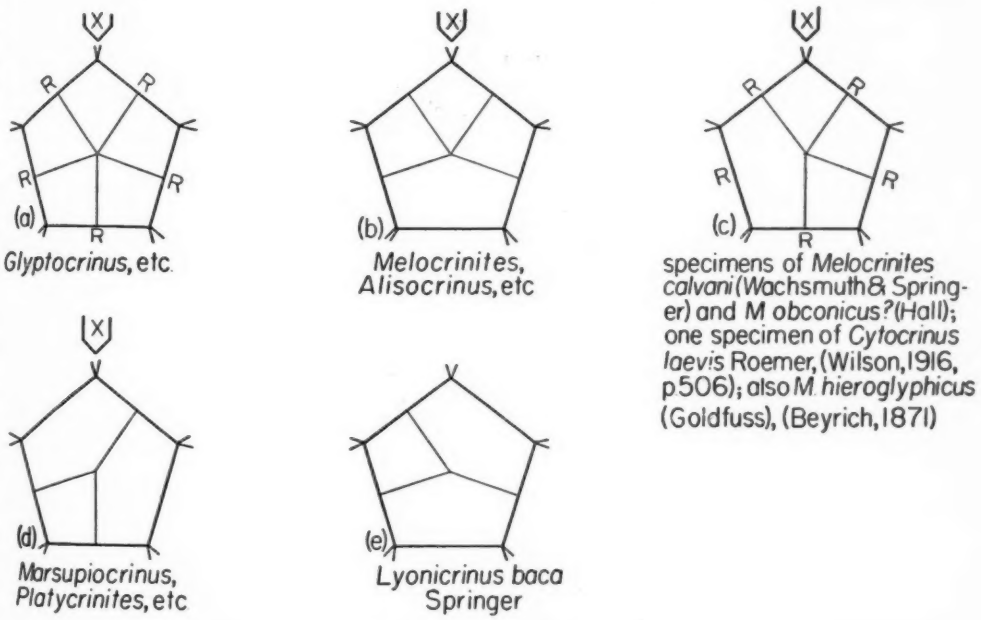


FIG. 2—Diagrams illustrating various basal plate arrangements described for pentagonal-based camerate crinoids.

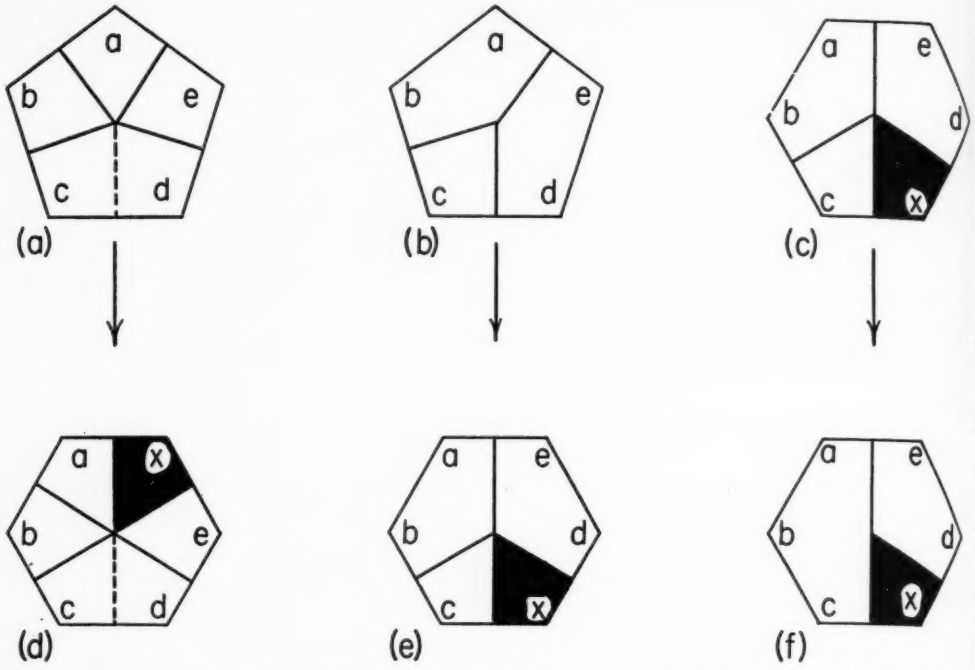


FIG. 3—Diagrams illustrating the Wachsmuth and Springer concept of the evolution of the various kinds of hexagonal monocyclic camerate bases. (After Wachsmuth and Springer, 1897, table A, p. 55.)

based camerates of the families Tanaocrinidae and Xenocrinidae from a pentapartite, pentagonal-based crinoid, one of the Glyptocrinidae (figs. 4a–c).

(2) The appearance of a posteriorly directed suture in tripartite and bipartite hexagonal bases through the atrophy of the right half of the posterior basal plus a compensating hypertrophy of the right posterior basal in a pentagonal base, accompanied by the process of truncation and enlargement of the posterior side as described above (figs. 4d–j).

(3) Anchylosis of sutures as recognized by Wachsmuth and Springer.

EVOLUTION OF THE BASES OF MONOCYCLIC CAMERATE CRINOIDS

The authors support the thesis of Moore and Laudon (1943) that monocyclic camerates having pentagonal bases descended from hexagonally based forms. The most primitive family of the pentagonal-based Monobathrida is the Glyptocrinidae, all of which have a pentapartite base. The earliest representatives of this family appear in rocks of Middle Ordovician (Mohawkian) age. These we believe descended from a hexagonal-based camerate with five basals, i.e., an early tanaocrinoid, "as is indicated by general form of the cup, prominent stellate plates, distinct median ray ridges, depressed interbrachial areas and other structural resemblances" (Moore and Laudon, 1943, p. 88). This evolution was accomplished, we believe, through upward elimination of the anal plate from the radial circlet, accompanied by a simple decrease in the size of the posterior basal (figs. 5i,f). It is in the absence of the anal plate from the radial circlet and possession of five equal basals that *Glyptocrinus* differs from *Compsocrinus*, a tanaocrinoid.

An obstacle to this theory of camerate evolution is the fact that no hexagonal-based, monocyclic camerate has been found in rocks older than Upper Ordovician (Cincinnatian). Although it is recognized

that to some the necessity for postulating a hypothetical ancestor may seem to weaken an evolutionary scheme, it appears to the authors to be the most logical solution in this case, for the following reasons.

Disregarding the factor of basal structure, the Glyptocrinidae show advances over the Tanaocrinidae in other features so that they could not have been ancestral to the Tanaocrinidae in spite of their earlier stratigraphic occurrence. In the Glyptocrinidae, the anal ridge, a primitive characteristic, has disappeared and interbrachial plates are larger and fewer than in *Tanaocrinus*, an evolutionary advance.

Neither could the Glyptocrinidae have descended from such tanaocrinoids as *Compsocrinus* as suggested by Moore and Laudon (1943, p. 81, fig. 43, p. 96) nor *Xenocrinus*, another primitive camerate of the tanaocrinoid stock, as they show evolutionary advancement over the glyptocrinoids in the reduction of the basal plates from five to four. The late stratigraphic occurrence (Cincinnatian) of *Xenocrinus* and the Tanaocrinidae is a further obstacle. For these reasons it is deemed more probable to assume that the Glyptocrinidae descended from an unknown, early or medial Ordovician, hexagonal-based camerate similar to *Tanaocrinus*

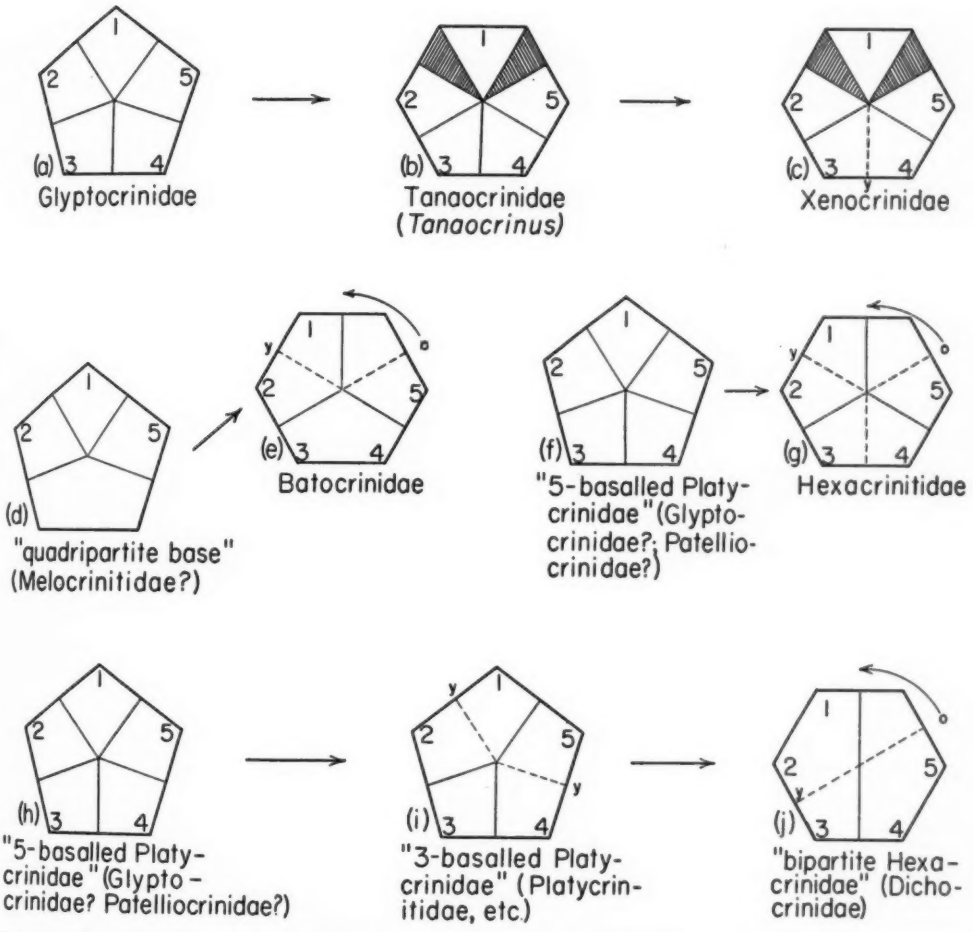


FIG. 4—Diagrams summarizing Wilson's (1916) views concerning the direction of evolution in monocyclic camerate crinoids. y = suture lost through anchylosis; o = suture which shifts position through hypertrophy of plate 5 and atrophy of the right half of plate 1.

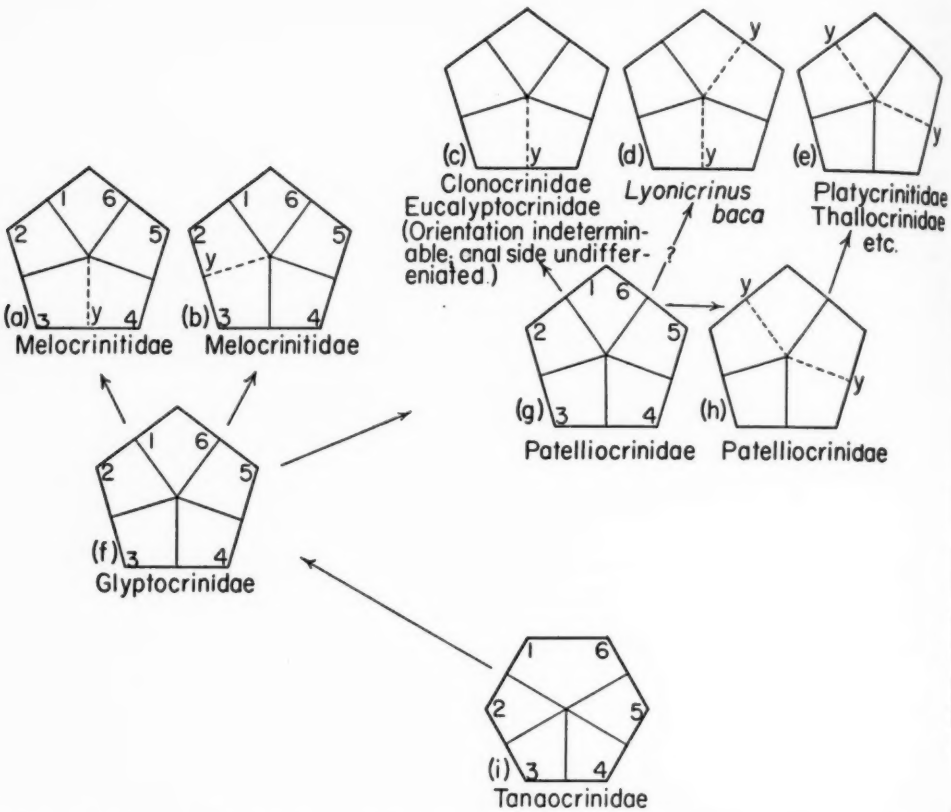


FIG. 5—Diagrams illustrating the evolution of various types of basal plate arrangements in pentagonal-based Monobathrida. y = suture lost through anchylosis. Errata: (d) should read *Lyonicrinus bacca*.

(fig. 5). There are no other described monocyclic camerates from which they could have descended.

Moore and Laudon (1943, p. 12) have suggested that the anal series of camerates had its origin in a sixth ray. Not only the position of the anal plate within the radial circlet supports this view, but also the axial ridge on the plates of the anal series of primitive camerates is similar to the axial ridge of the ray series. With time the anal ridge disappeared, but in earlier camerates such as *Reteocrinus*, *Xenocrinus*, and *Compsocrinus*, it is as pronounced as ridges which traverse the rays.

Wilson (1916, p. 550) attempted to show that the ridges on *Compsocrinus* and *Xenocrinus* are comparable to the ridges on the interradial arms of the modern *Thaumatocrinus*. However, his figures are not at all convincing (fig. 6) and he admits that the evidence is highly conjectural and not to be relied upon.

Examination of the nerve ridges which appear on the basals of camerates and their relationship to the ridges on overlying radials shows that the large, posterior basal in the Tanaocrinidae has a nerve chord arrangement similar to that of a compound basal, i.e., the large, anterior basal of *Xenocrinus* and *Compsocrinus* (fig. 7). This suggests that the large, posterior basal may be, in reality, a compound basal originating through the fusion of two small posterior basals of a hexapartite, hexagonal-based echinoderm, the ancestor of the Tanaocrinidae.

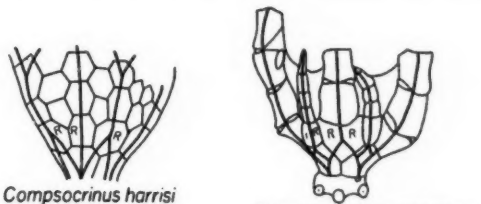
Much has been made by earlier authors of the pentamerous symmetry of echinoderms in postulating that pentagonal-based cri-

noids are primary and primitive. However, many cystoids, most primitive of echinoderms, do not possess a pentamerous symmetry. It is possible that pentamerous symmetry is a secondary development among echinoderms. Examination of dicyclic camerates supports the view that pentamerous symmetry was a secondary modification in the Echinodermata. Wachsmuth and Springer (1897, p. 59) stated that "the interpolation of an anal into the radial circlet of dicyclic crinoids did not affect them as it did monocyclic forms." However, the dicyclic camerates actually show an evolutionary history similar to that suggested here for their monocyclic relatives. The earliest dicyclic camerates have the anal plate within the radial circlet. The anal area, wide at first, was gradually reduced in size. Not until the Silurian period did *Nyctocrinus* appear, the only dicyclic genus in which the anal plate is out of the radial circlet.

Pentagonal bases.—The development of the various types of bases in pentagonal-based Monobathrida seems to have proceeded through the anchylosis of sutures to produce crinoids having unequally quadripartite and tripartite bases (fig. 5).

Tripartite bases developed from pentapartite rather than from a quadripartite base. With the exception of the tripartite base of *Lyonocrinus bacca* Springer (fig. 2e), in all of the tripartite bases of the pentagonal-based group, the small basal is in a left anterior position, and the right anterior and left posterior sutures are anchylosed. No quadripartite bases are known from which such a base could have originated inasmuch as the anchylosed suture is in the wrong position in both types of basal plate arrangements described for quadripartite-based Melocrinitidae. The authors agree with Wilson (1916, pp. 679, 682) that, whereas a suture may occasionally reappear through failure of anchylosis in an individual crinoid, this does not occur phylogenetically.

It does not seem possible that the quadripartite-based Eucalyptocrinidae and Clonocrinidae could have been ancestral to the tripartite-based patelliocrinoid stock since these families are specialized forms in which the anal interradius is similar to the other interradii. Therefore, from the consideration of basal structure, the tripartite, pentagonal-based Platycrinitidae, Thallocrinidae, and Patelliocrinidae must have descended ultimately from pentapartite-based crinoids. The inferred evolution of the families of the pentagonal-based Monobathrida is shown in figure 5.



Compsocrinus harrisi Miller

Thaumatocrinus renovatus Carpenter

FIG. 6—Diagram showing the course of the radial and anal ridges in *Compsocrinus* and the branching of the nerves in *Thaumatocrinus* (after Wilson, 1924, fig. 8, p. 550).

Hexagonal bases.—There are within the hexagonal-based Monobathrida four normal arrangements of basal plates. These are shown in figures 1a, b, c, and d. The derivation of the quadripartite (fig. 1b) from the pentapartite (fig. 1a) requires only a simple anchylosis of the anterior suture (fig. 8).

The derivation of the equally tripartite base (fig. 1c) is a more difficult problem. Wachsmuth and Springer derived this type of base from an unequally tripartite, pentagonal base by the addition of an x element to the left anterior basal (figs. 3b and c). Wilson derived this type of base in two ways: (a) from a quadripartite, pentagonal base (figs. 4d and e); and (2) from a pentapartite, pentagonal base (figs. 4f and g). In both cases he suggests a combination of plate atrophy and compensating hypertrophy as factors which would achieve such a result.

While we do not agree with Wilson's

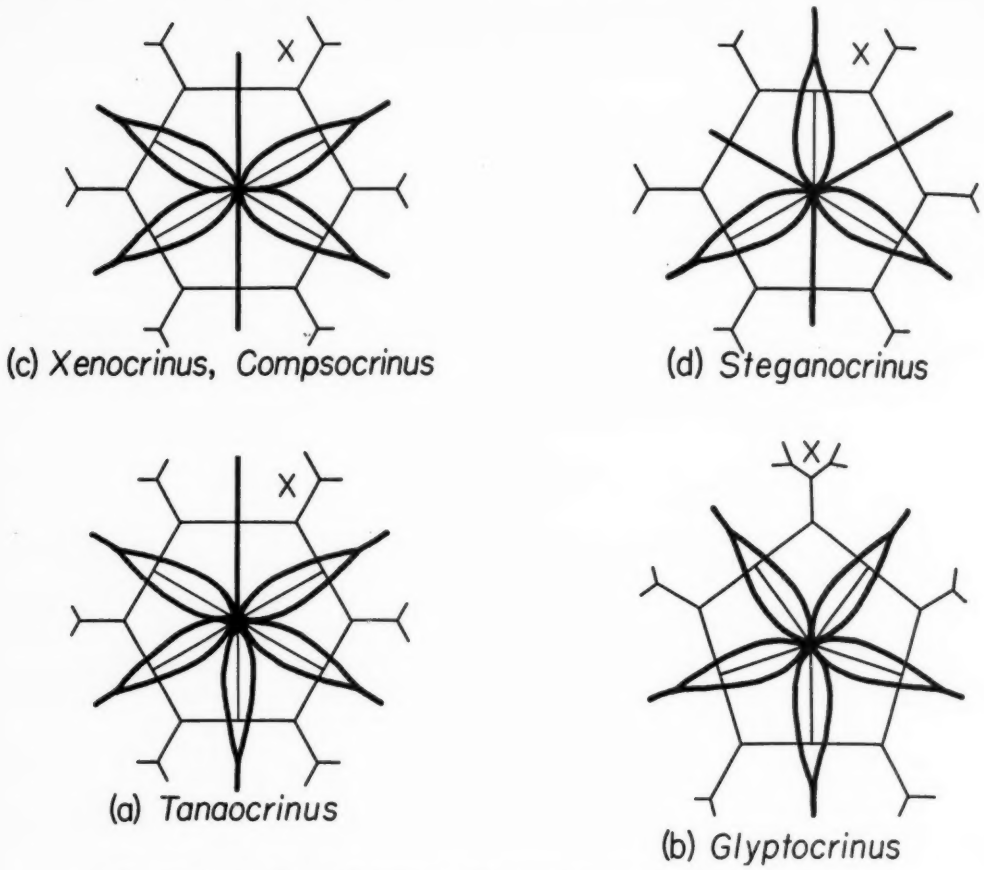


FIG. 7—Diagrams showing nerve ridge patterns in various monocyclic camerates.

line of evolution, we more or less accept his concept of plate atrophy and hypertrophy as a plausible explanation of the evolutionary changes that occurred in hexagonal bases to produce not only the tripartite but also the bipartite base.

It is the contention of the writers that the tripartite, hexagonal base was derived from a quadripartite, hexagonal base through the failure (atrophy) of the posterior basal to develop, accompanied by a compensating overdevelopment of the adjacent lateral basals (2 and 5 in diagrams, fig. 8). Among hexagonal-based Monobathrida, the tripartite base is the most common form.

The bipartite base characterizing the Dichocrinidae was developed, we believe, by the same process operating on the anterior side of the base. In other words, with the nondevelopment of the compound anterior basal (3 and 4 of fig. 8), the lateral basals (2 and 5, fig. 8) enlarged symmetrically, joining along a newly formed anterior suture.

It is interesting to note that Beyrich (1871, p. 33) suggested the process of the inhibition of development of a basal plate plus the enlargement of an adjacent plate as a possible explanation of the reduction in number of basals in pentagonal-based crinoids.

Abnormal hexagonal bases.—The theory outlined above for the development of the various plate arrangements in hexagonal bases can also be applied as an explanation of the abnormal bases illustrated by Wilson (1916, plates 1–3) and shown in figure 1.

The abnormal, four-basalled *Batocrinus* fig. 1m) is easily the result of the reappearance in an individual of the anterior suture

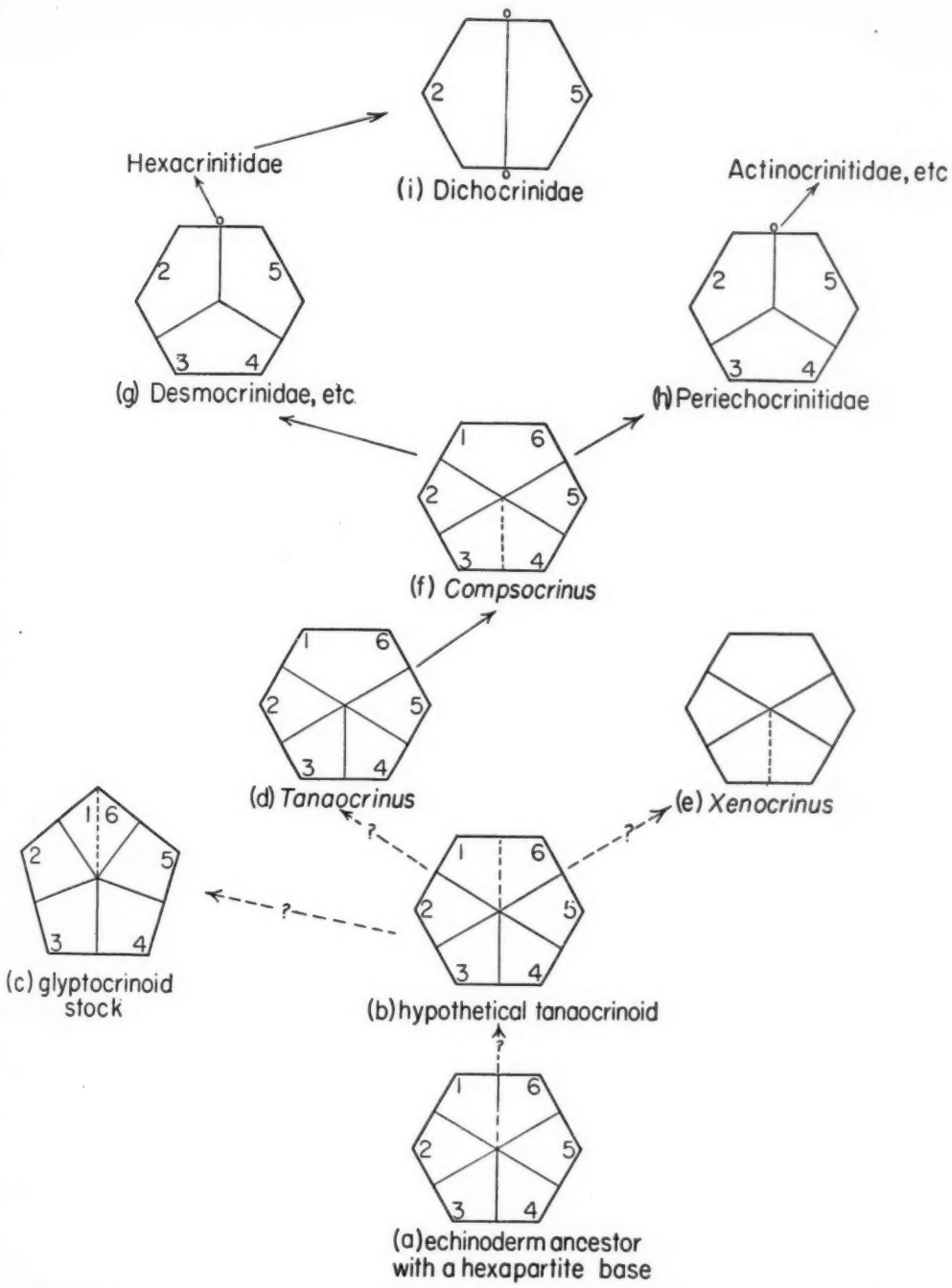


FIG. 8—Diagrams illustrating the evolution of various types of basal plate arrangements in hexagonal-based Monobathrida. y = suture lost through anchylosis; o = suture formed by overdevelopment of plates 2 and 5.

not present in normal Batocrinidae, due to failure of anchylosis.

The three abnormal specimens of *Steganocrinus pentagonus* and the abnormal *Hexacrinites anaglypticus* (figs. 1e–h), present a more difficult problem. If the views advanced by the writers concerning the manner of development of normal, tripartite, hexagonal-based Monobathrida are correct, then these abnormal bases are the result of incomplete development of one of the three plates with compensating overdevelopment of an adjacent plate. In the two-basalled *Steganocrinus* (fig. 1f) the anterior basal did not develop, and the right posterior and left posterior basals enlarged to meet along an anterior suture. In this specimen it would seem that the right side of the left posterior basal was likewise not developed, perhaps inhibited by the excessive growth of the right posterior basal.

The small basal plate in the two abnormal specimens of *Talarocrinus patei* (figs. 1k and l) are, accordingly, the result of the partial reappearance of a plate which had disappeared during the evolution of the Dichocrinidae.

In other words, the factors operative to produce these abnormal forms are the same as those which operated to produce the evolutionary development of normal tripartite bases from quadripartite.

Evolution of the major families of the hexagonal-based Monobathrida is outlined in figure 8. Factors other than basal structure have been considered in formulating this outline as some of the families with similar bases possess other highly specialized characters which must be considered in a plan of evolutionary development.

PLATE REDUCTION OR LOSS

The reduction in size or complete disappearance of a plate from a cycle can be, as far as is presently known, the result of one of the following processes.

(1) Absorption by ameboid cells which "take calcareous salts into solution and transmit them to depositional cells" (Wilson, 1916, p. 503). This is evidently the process operative in the absorption of the anal and oral plates in the ontogenetic development of the modern crinoid *Antedon*.

If absorption was the process responsible for the elimination of the posterior and anterior basals in the development of tripartite and bipartite hexagonal bases, then it must be assumed that these plates developed during the larval stages of the crinoid but were absorbed before maturity while the lateral basals continued to grow, filling the space left by the absorbed plates. Unfortunately, since the larval stages of these crinoids have evidently not been preserved, or at least have never been described, it is impossible to ascertain whether plate absorption was the factor responsible for the formation of the tripartite and bipartite hexagonal bases. Development of abnormal camerate bases such as are shown in figure 1, lends support to the argument that absorption was the responsible factor. This is especially true of the abnormal specimens of *Talarocrinus patei* (figs. 1k and l) in which the small, extra plate would thus be the result of incomplete absorption.

(2) Failure to develop; i.e., the inhibition of growth of a plate, the result of changes within the organism itself. This is evidently the process Wilson (1916) refers to as a "deep-seated atrophy." Such a morphological change could become a permanent phylogenetic character, and could quite plausibly account for the changes in basal plate structure observed in the hexagonal-based Monobathrida.

(3) Inhibition of growth as the result of accelerated growth of adjacent plates. It is improbable that this process is responsible for complete loss of the posterior and anterior basals in the development of normal tripartite and bipartite bases. However, it is possible that it could produce the abnormal specimens of *Steganocrinus pentagonus* and *Hexacrinites anaglypticus* shown in figure 1, in which one of the three basals is overdeveloped at the expense of another.

These three are the only possible processes known to the writers which could have produced the changes in base structure shown by the Monobathrida.

CONCLUSION

It is possible not only to derive a plausible evolutionary sequence of development of the bases of monocyclic camerates based upon the concepts of Moore and Laudon

(1943), but also to suggest methods by which such a development could have proceeded. This is in itself, we believe, effective support for the Moore and Laudon theory of camerate evolution.

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NOTICE

TENTH FIELD TRIP, MISSISSIPPI GEOLOGICAL SOCIETY SEPTEMBER 24, 25, 26, 1953

The Tenth Field Trip of the Mississippi Geological Society will be held September 24, 25, and 26, 1953, in the type area of the Wilcox and Midway sediments (lower Eocene and Paleocene), west-central Alabama. Trip leaders are: Mr. P. E. LaMoreaux, Dr. E. H. Rainwater and Dr. L. D. Toulmin. A guidebook covering the general geology of the area, detailed descriptions of the exposures to be visited, and a road log will be available.

Registration will take place at the Jefferson Davis Hotel, Montgomery, Alabama, the evening of September 24th between 5:00 P.M. and 6:00 P.M. A cocktail hour and a banquet are planned for the evening, and following the banquet there will be a panel discussion of the Wilcox-Midway stratigraphy of the Gulf Coast by:

Dr. L. D. Toulmin, for Alabama
Mr. F. F. Mellen and Mr. E. M. Rice, for Mississippi
Dr. Grover E. Murray, for Louisiana
Dr. H. B. Stenzel, for Texas

Room reservations for the night of September 24th should be made directly with the Jefferson Davis Hotel, Montgomery.

Friday night, September 25th, will be spent in Selma, Alabama. Room reservations should be sent to the Graystone Motel, Selma, Alabama, which will find rooms in other motels or hotels when the Graystone is full. *Please mention the Mississippi Geological Society when making hotel reservations.*

The Field Trip will end Saturday afternoon, September 26th at Naheola Landing about 50 miles east of Meridian, Mississippi.

Chartered air-conditioned buses will be available for the trip, leaving the Trailways Bus Station, Jackson, Mississippi at Noon, September 24th, returning to Jackson, Mississippi, Saturday afternoon, September 26th.

Those desiring to travel to Montgomery by plane may reserve seats on the chartered buses from Montgomery to Jackson, Mississippi.

Fare for the bus will be $14.00. Reservations, including the $14.00 fare, are to be made prior to September 15, 1953, with Claude D. Smith, c/o Union Producing Company, Box 1020, Jackson, Mississippi.

JOURNAL OF PALEONTOLOGY, VOL. 27, NO. 4, PP. 596–600, 25 TEXT FIGS., JULY 1953

WARRENELLA, A NEW GENUS OF DEVONIAN BRACHIOPODS[1]

C. H. CRICKMAY
Imperial Oil Limited, Calgary, Alberta, Canada

INTRODUCTION

IT HAS become evident to the writer in the course of paleontological work on collections brought in annually by the field geologists that the late Middle and early Upper Devonian could be zoned on the basis of the Martiniidae. Originally described as *Martinia* (with which, however, it is not congeneric), the species *M. franklinii* Meek agrees with none of the existing martiniid genera. Recently, several unnamed forms related to *M. franklinii* have been discovered. The existence of a group of such species, named and unnamed, emphasizes the need for a proper generic denomination.

SYSTEMATIC DESCRIPTIONS

Class BRACHIOPODA
Superfamily SPIRIFERACEA
Family MARTINIIDAE

Genus WARRENELLA Crickmay, n. gen.

Genotype.—*Warrenella eclectea* Crickmay, n. sp.

Diagnosis.—Smooth, robust, strongly umbonate Martiniidae with umbonal callus extending in anterior direction over much of interior.

Ventral valve strongly convex, sulcate, lined interiorly with thick, extensive, symmetrically developed callus. Teeth well developed. Dental lamellae long, approximate, slightly divergent, dying out basally in umbonal callus. Delthyrium of medium width, closed by a strong, short deltidium.

Dorsal valve convex, uniplicate, lined with much callus. Cardinal process short, sagittally striate. Hinge-plate deeply cleft. Sockets large, deep, with prominent bordering ridges. Spiralia with seven to nine turns.

Discussion.—Since one species, *W. franklinii*, has a micro-ornament, it is probable that this will prove to be a generic characteristic, though without very superior preservation it will not be observed. *Warrenella* is distinct from *Martinia* which lacks dental lamellae, and from *Martiniopsis* and *Martiniella* which lack the extensive internal callus and such associated structural modifications as reduced dental lamellae. *Warrenella* is one of the few Devonian representatives of this family, other genera being mainly Mississippian to Permian.

The name of the new genus is given in compliment to Professor P. S. Warren, University of Alberta, the outstanding pioneer of western Canadian paleontology.

WARRENELLA ECLECTEA Crickmay, n. sp.
Figures 1–5, 16–19

Shell of small or sub-medium size, smooth, strongly but unequally biconvex. Anterior commissure strongly uniplicate to faintly parasulcate. Hinge-line 75% of total width.

Ventral valve strongly convex, deep and wide in ratio with length. Beak incurved, abruptly tapered, acute, regular in median section, symmetrical. Interarea long (24% of hinge length), not sharply delimited. Delthyrium of medium width, deltidium short. Sulcus beginning immediately anterior to umbo, inconspicuous and shallow in posterior region, expanding and deepening at a rate greater than the normal growth curves. Apical callus very thick, extending more than half-way to anterior borders, pierced by small apical and umbonal vaults. Dental lamellae sub-parallel, ending basally in a rounded arch. Teeth large.

Brachial valve of medium convexity. Beak and dorsal interarea conspicuous. Fold beginning anterior to umbo, expanding similarly to sulcus, markedly flaring at anterior end. Cardinal process small, round, boss-like, deeply and finely striate, bordered by greater striae. Sockets large, bordered by sharp ridges. Apical callus thick, extending one-half way to anterior border, thinner in a narrow median zone with square-cut walls. Spiralia with seven to eight turns.

Holotype width, 22.5 mm.; length, 18 mm.; length of brachial valve, 14.5 mm.; depth (valves together), 14 mm.

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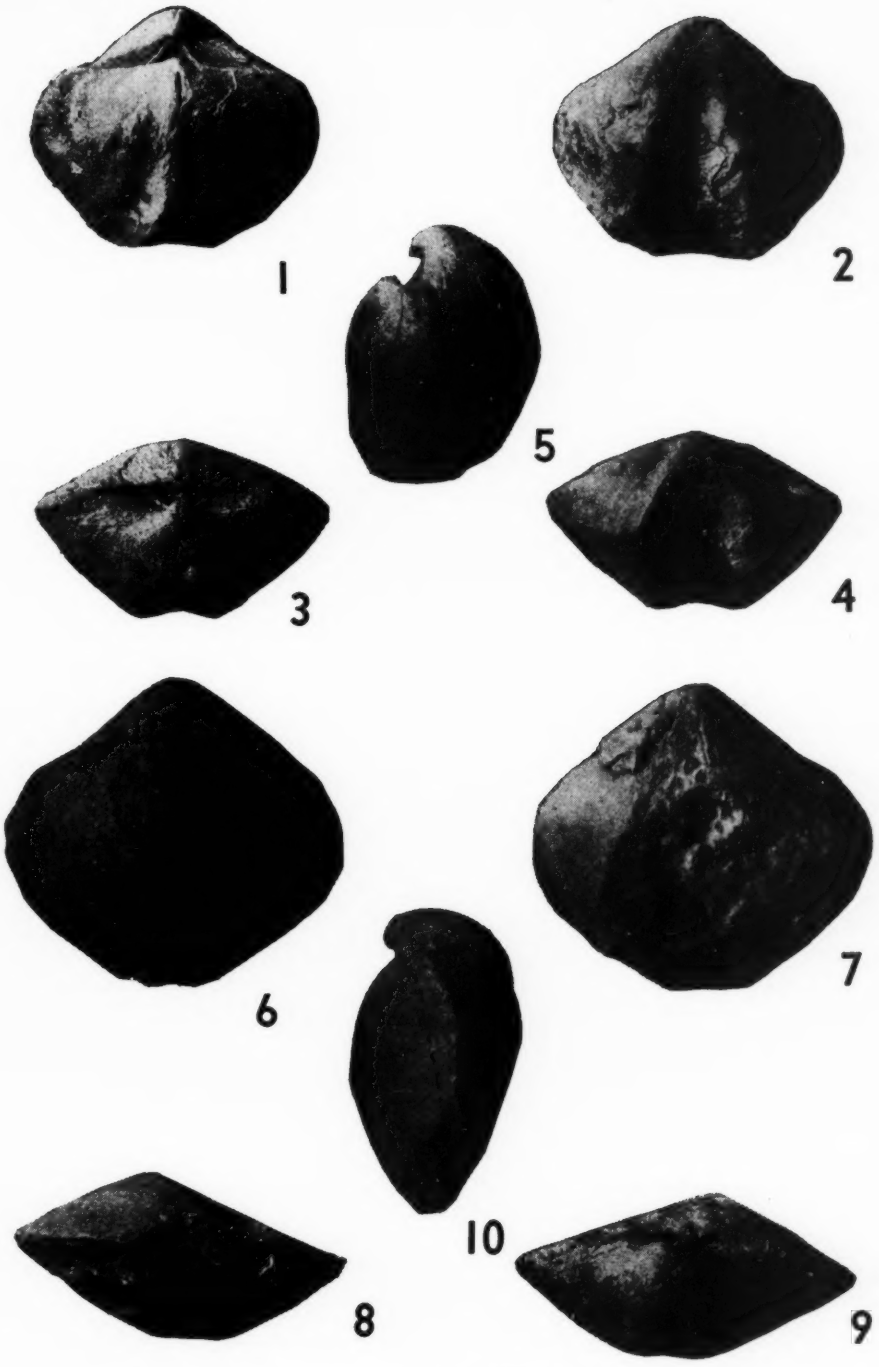

EXPLANATION OF FIGURES *1–10*

FIGS. *1–5—Warrenella eclectea* Crickmay, n. sp., holotype, dorsal, ventral, posterior, anterior, and left lateral views; all ×2.2. (p. 596)

6–10—Warrenella apodecta Crickmay, n. sp., holotype, dorsal, ventral, anterior, posterior, and left lateral views; all ×2.2. (p. 598)

Occurrence.—West upper slope of Mt. Mackenzie, Township 45, Range 23 West of 5th Meridian, Alberta, Canada; lower 40 feet of Cheviot formation.

WARRENELLA APODECTA Crickmay, n. sp.
Figures 6–10, 11–15

Shell of small or sub-medium size, smooth, not strongly nor very unequally biconvex. Anterior commissure gently uniplicate. Hinge-line, 52% of total width.

Ventral valve gently convex, of medium depth, slightly wider than long. Beak strongly incurved, abruptly tapered, acute, regular in median section, symmetrical. Interarea short, not delimited in any way. Delthyrium of medium width (60°); deltidium very short. Sulcus beginning much anterior to umbo, inconspicuous, shallow and of moderate width even at anterior end. Apical callus thick, extending more than half-way to anterior borders. Dental lamellae divergent, deeply embedded basally in callus, appearing to extend at one stage of development to floor of valve, joined by a transverse structure which becomes anteriorly the convex surface of the median zone of callus. Teeth small.

Brachial valve of low convexity. Beak and dorsal interarea less conspicuous than in other species. Fold very inconspicuous at all stages. Cardinal process prominent, with a small concave crown, very deeply and finely striate. Sockets small. Apical callus thick only in umbonal region, extending thinly over interior more than half-way to anterior border, thinner in a median zone with low square-cut walls. Spiralia with seven to eight turns.

Holotype width 23 mm.; length, 20 mm.; length of brachial valve, 16 mm.; depth (valves together), 10.5 mm.

Occurrence.—West upper slope of Roche à Perdrix, Township 49, Range 27 West of 5th Meridian, Alberta, Canada; uppermost bed of Flume formation.

WARRENELLA FRANKLINII (Meek)
Figures 20–25

Spirifer (Martinia) franklinii MEEK, 1867, Trans. Chicago Acad. Sci., vol. 1, art. 3, pl. 14, figs. 12a, 12b, 12c.

Shell rather large, orbicular, strongly but unequally biconvex. Anterior commissure uniplicate. Hinge-line, 75% of total width.

Ventral valve strongly convex, deep. Beak strongly incurved, abruptly tapered, regular in median section, symmetrical. Interarea short, strongly curved, sharply marked by ridge from beak to hinge extremity, striated both ways. Delthyrium short, of medium width (60°); deltidium short (about 50% of delthyrium). Sulcus beginning on umbo, narrow, shallow, flaring at anterior margin. Apical callus very thick, extending over entire interior, pierced by small apical and umbonal vaults. Dental lamellae subparallel, ending basally on surface of callus, or embedded in callus in apical region. Teeth large.

Brachial valve moderately convex. Beak and dorsal interarea very conspicuous. Fold obscure or lacking from posterior region, low and ill-defined in anterior region. Apical callus thick only in apical region, lacking from remainder of interior. Spiralia with eight to nine turns. Surface apparently smooth, but with a micro-ornament of short (0.1 mm.) radial threads disposed in concentric groups 1.5 mm. apart.

Discussion.—The description given above, though mainly derived from fresh material, is essentially that written by Meek when he named the species. In most specimens, the length of the hinge is less than Meek's figure of 75% of total width, being commonly as low as 60%. Meek's wording has

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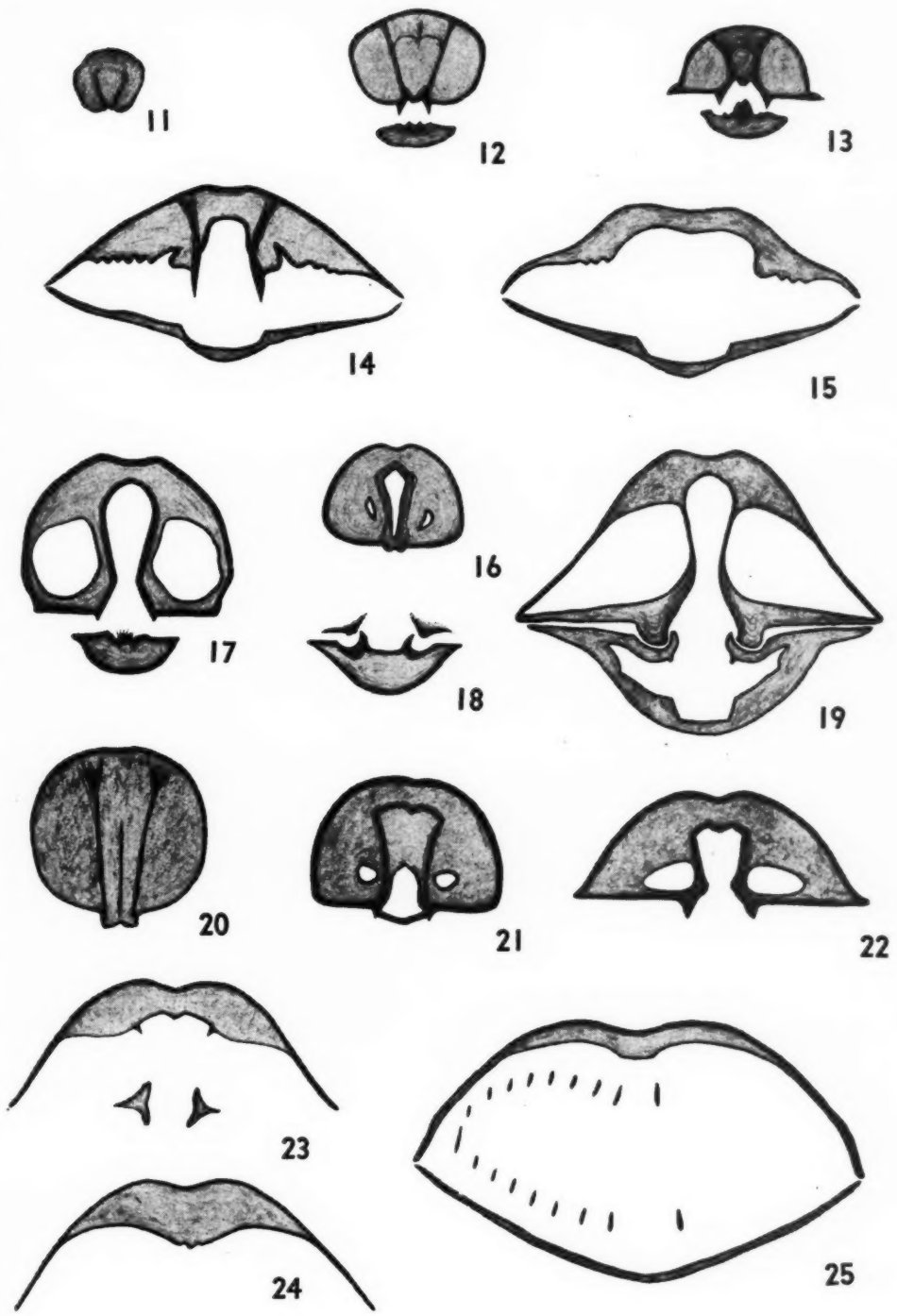
EXPLANATION OF FIGURES *11–25*

FIGS. *11–15*—*Warrenella apodecta* Crickmay, n. sp., paratype no. 1, cross-sections from beak to central region. Fig. *11*, ×2.5; *12*, ×3; *13*, ×2.7; *14*, ×2.4. *15*, ×2.4, is taken at mid-length. (p. 598)

16–19—*Warrenella eclectea* Crickmay, n. sp., paratype no. 1, cross-sections from beak to central region. Fig. *16*, ×3.25; *17*, ×3.5; *18*, ×3.25; *19*, ×3.4. (p. 596)

20–25—*Warrenella franklinii* (Meek), typical specimen, cross-sections from beak to central region. Fig. *20*, ×5; *21*, ×2.5; *22*, ×2.25; *23*, ×2.1; *24*, ×1.9. Fig. *25*, ×2.1, is taken at midlength. (p. 598)



FIGS. *11–25*.

been translated into the current terminology, as, for instance, the writer uses delthyrium and deltidium for Meek's foramen and pseudodeltidium; currently, foramen means the functional opening, and pseudodeltidium is becoming a discredited word.

Meek remarks of the surface of the shell, "under a magnifier, very fine, obscure, closely arranged concentric striae, with some appearance of minute radiating striae." Most specimens have none of this preserved.

Meek's specimen, width, 1.94 inches (=50 mm.); length, 1.80 inches (=45.5 mm.); length of brachial valve, 1.47 inches (=37 mm.); depth (valves together= "convexity of the two valves"), 1.24 inches (=31.5 mm.). Length of hinge, 1.54 inches.

Occurrence.—"Mackenzie River, forty miles below the Ramparts" (Meek, 1867). Beavertail formation.

GENERAL CONCLUSIONS

The genus *Warrenella*, as indicated by the three species now known, ranges from Middle to early Upper Devonian. *W. franklinii* occurs in the Beavertail and Slave Point formations, in other words, in immediately post-*Stringocephalus* deposits. Were the basal beds of the Beaverhill Lake formation sufficiently fossiliferous, it would be expected in them. *W. apodecta* is a companion of *Eleutherokomma jasperensis*. Known so far only from the Rocky Mountains, it might be looked for in about the third fragmental limestone member of the Beaverhill Lake formation, and in company with *Caryorhynchus castanea* var. in the Fort Creek black shales of the Mackenzie basin. *W. eclectea* occurs in the Rocky Mountains at the base of the Cheviot formation with *Caryorhynchus carya* Crickmay, its horizon corresponding to uppermost Duvernay member or lowest Ireton member of the central Alberta column, or, in other words, immediately pre-*Cyrtospirifer* deposits.

In regions other than Alberta, there appear to be several named species in Middle and early Upper Devonian deposits that will prove, when sufficiently thoroughly studied, to be referable to *Warrenella*.

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JOURNAL OF PALEONTOLOGY, VOL. 27, NO. 4, PP. 601–609, 9 TEXT FIGS., JULY 1953

PALEONTOLOGICAL NOTES

SOME REMARKS ABOUT THE PLIO-PLEISTOCENE MICROBIOSTRATIGRAPHY IN NORTHWESTERN EUROPE AND IN NORTH AMERICA

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INTRODUCTION

OUR appeal to European and American workers on Plio-Pleistocene telecorrelation only makes sense if we can mutually agree on two important points:

1. The assurance that the basis for all Pleistocene stratigraphy rests on major climatic oscillations that are world-wide and broadly synchronous, and,
2. The conclusion of the Commission on the Plio-Pleistocene boundary of the International Geological Congress in London, 1948, that this boundary should be based on changes in marine faunas, since this is the classic method of grouping fossiliferous strata.

Although we are certainly not familiar with the American Plio-Pleistocene stratigraphy, we think it nevertheless worthwhile to give here not only a short summary of our European research work, but also our opinion about the possibility of a more fruitful contact between workers who are studying the same subject on both sides of the Atlantic. This cooperation seems still more urgent since one of the purposes of the new trend of sea-floor geology undoubtedly will be the building of a paleogeographical bridge between North America and northwestern Europe.

We will first try to give a very short summary of our own microbiostratigraphical work and thereafter give our opinion about some of the American stratigraphical results on the same subject. This opinion is based on our experience on the European side of the Atlantic, and, therefore, is very tentative and subject to change.

DISTRIBUTION OF IMPORTANT GUIDE-MARKERS IN SPACE AND TIME

It is evident that for correlation purposes the whole foraminiferal assemblage has to be considered. We elect here only two species, *Elphidiella arctica* (Parker and Jones) and *Elphidium oregonensis* Cushman and Grant.

Elphidiella arctica seems to be an important climatic indicator. In a previously published short note we considered the Recent distribution of this species (van Voorthuysen, 1949). The southernmost recorded occurrence in northwestern Europe is latitude 53°43′ N. (west coast of Ireland, R on fig. 1). In North America this form occurs as far south as latitude 41°30′ N. (Buzzards Bay, near Cape Cod, R on fig. 1). On the map (fig. 1) we plotted the distribution of the form-range of *E. arctica* in Recent time, in late glacial time (hitherto only known from Norway, Sweden and Denmark), and in the older Pleistocene (in America called *E. hannai* Cushman and Grant and in Europe *E.* cf. *E. arctica*).

If we consider the Recent distribution of *E. arctica*, we will see that it occurs in America much farther south than in Europe. In northwestern Europe (west coast of Ireland at one isolated locality) the southernmost distribution is situated between the summer isotherms of 10° and 15°C.; along America's eastern coast, on the other hand, between 20° and 25°C. This may be due to the southwestern drawing off of the cold Labrador Stream.

In Calabria, Italy, at latitude 39°N. is the classic type locality of the Calabrian (marine equivalent of the Villafranchian). In these oldest Pleistocene sediments of the Mediterranean, *E. arctica* is wanting in the faunal assemblage, most probably due to higher temperatures in that region during Pleistocene time.

We are almost sure that *Elphidiella hannai* and *Elphidiella* cf. *E. artica* of our oldest Pleistocene are synonymous. In the Pleisto-

cene sediments of northwestern Europe, we can distinguish a younger Pleistocene form (fig. 2, B) characterized by a rounded edge of the test (not previously mentioned from North America) and an older Pleistocene form (fig. 2, C) possessing a more abruptly rounded gothic-arch edge like the American *E. hannai*. Because of the transition between these two forms, we are not presently able to give an exact phylogenetic range through the Pleistocene.

Figure 2 gives a rough distribution of the form-range *E. arctica—E. hannai—E.* cf. *E. arctica* in northwestern Europe during the Quarternary. As far as we learned by comparison with the Recent specimens of *Elphidiella arctica*, kindly supplied by Mr. C. D. Ovey, these forms are not identical with examples from our younger Pleistocene. The latter exhibit a somewhat differently rounded edge of the test, as indicated by A and B in figure 2.

According to American workers, *Elphidiella hannai* lives also in Recent time along the American west coast (Mexico) and the east coast. As we are almost sure that *E. hannai* is identical with our *Elphidiella* cf. *E. arctica*, possessing a gothic-edged test, and inasmuch as our form, as far as we know, does not occur in living conditions along the coast of northwestern Europe, we presume that either *E. hannai* has only maintained itself in North America throughout Pleistocene and Recent time, or that this occurrence in Recent sediments is due to redeposition from the Pleistocene beds located near or along the American coast. In either case, *E. hannai* does not occur everywhere along the coast of California, for Natland (1933) does not mention it in his range chart of the Recent sediments of the San Pedro Bay and channel (P on fig. 1).

Our work with the quantitative distribution of Foraminifera has taught us that conclusions based on the fossil content of a single sample may be rather uncertain. Owing to rapid facies shift or to mechanical factors, especially under littoral and estuarine conditions, the results of faunal analysis can change considerably from sample to sample in the geological column.

What we learn from the American literature about Plio-Pleistocene micropaleontological studies is based, in most cases, on scattered samples, and not on completely sampled profiles.

We found in our earliest Pleistocene sediments (Amstelian) many specimens of *Elphidium oregonensis* Cushman and Grant (van Voorthuysen, 1952). Considering the very extensive distribution area of the fossil

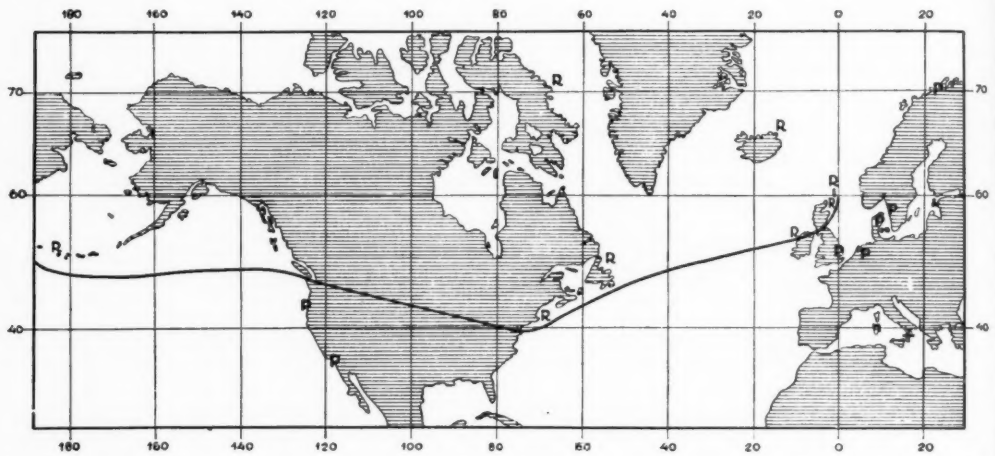

FIG. 1—Distribution of the form-range *Elphidiella arctica—E. hannai—Elphidiella* cf. *E. arctica* in space and time. R = occurrence in Recent time of *E. arctica;* P = occurrence in Pleistocene time of the form-range *E. arctica—E. hannai—E.* cf. *E. arctica;* + = does not occur in Pleistocene time (Calabria, Italy).

FIG. 2—Distribution of the form-range *Elphidiella arctica—E. hannai—Elphidiella* cf. *E. arctica* in the geological column of northwestern Europe.

and Recent form-range of *E. arctica*—*E.* cf. *E. arctica*—*E. hannai*, we presume that the large and striking *E. oregonensis*, which hitherto always has been found together with the above-mentioned form-range, will also be an important guidemarker for the oldest Pleistocene on both sides of the Atlantic.

CENOZOIC FORAMINIFERA FROM CAPE BLANCO, OREGON

A study of foraminifers from Cape Blanco, Oregon (P on fig. 1), by Orville L. Bandy (1950) seems to be an important contribution to the microbiostratigraphy of the American Plio-Pleistocene of the American west coast.

Judging from European standards, however, we should declare that the middle or upper Pliocene Port Orford formation, having 60% *E. hannai* and 5% *Eponides frigidus*, is of Amstelian age (Red Crag-Calabrian-Villafranchian-oldest Pleistocene). The Pleistocene *E. hannai* zone of the Elk River formation possesses nearly the same faunal assemblage as a typical facies of our Amstelian (van Voorthuysen, 1952).

The Pleistocene *Rotalia tenerrima* zone of this same formation should be, from the European point of view, either of Holocene age or deposited in a rather warm interglacial or interstadial time.

If we compare the fossil content of the Pliocene of Cape Blanco, Oregon, with those of Timms Point, California (Cushman and Gray, 1946), we have to establish a great difference. The faunal assemblage of Timms Point, it is true, presents most probably a deeper sea facies, but it is still amazing that it does not contain a single *Elphidiella hannai*, nor could we find this species in topotypic (recollected) material kindly supplied by Mr. Zach M. Arnold from the Museum of Paleontology, University of California, Berkeley.

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A NEW SPECIES OF *ARCHAEOCRINUS* FROM OKLAHOMA

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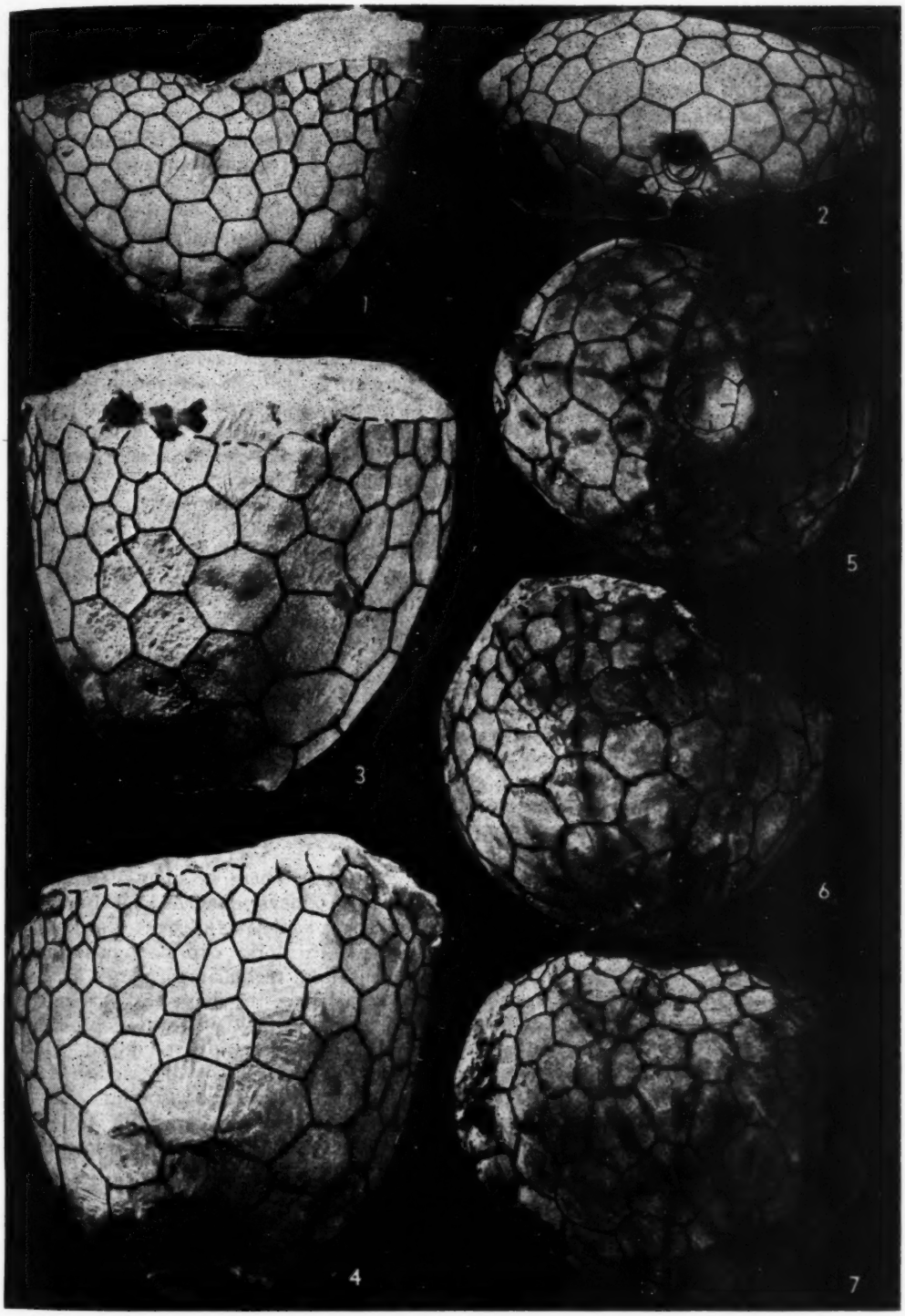
THIS paper deals with one of the most common forms of *Archaeocrinus* occurring in the Criner Hills of southern Oklahoma. It is described as *A. subovalis*, n. sp. The holotype and some paratypes are from a Bromide formation (Ordovician) exposure known to many geologists as "Rock Crossing" located in the bank of Hickory Creek, southwest of Ardmore, Oklahoma. Several paratypes were found in the bank of Spring Creek, a tributary of Hickory Creek. On one collecting expedition to the Spring Creek locality, Wm. T. Watkins, of San Antonio, Texas, and the author dug out over 100 specimens as one might grub out a potato mound, but unfortunately all were in a relatively poor state of preservation. The species is unusually susceptible to erosive action owing to the thinness of the plates. Ten specimens which show the sutures of the plates quite well are selected as types, one being designated as the holotype and the other nine as paratypes. There are over 100 metatypes.



EXPLANATION OF FIGURES

FIGS. *1–7*—*Archaeocrinus subovalis*, n. sp. Paratype viewed from *1*, left posterior and *2*, below (post. IR to the top), ×1.4. Holotype viewed from *3*, anterior and *4*, posterior, ×2.2. Paratype viewed from *5*, base (post. IR to the upper left); *6*, oblique left anterior and *7*, left posterior, ×1.4.

(p. 606)

DESCRIPTION OF SPECIES

ARCHAEOCRINUS SUBOVALIS Strimple, n. sp.

Figures 1–7

Dorsal cup is in the form of a rather high, basally impressed bowl. The basal concavity is marked by a strong rim which takes the form of a pentagon, with the angles in mid-portions of the basal plates.

There are five infrabasals (IBB) restricted to the basal concavity; five basals (BB) partially within the impressed base, but with distal portions participating in the lateral walls of the cup; five radials (RR) which are separated by interradials (IRR); each interray has one IR, and the posterior one is the anal (X).

Each radial plate is followed by two primibrachials (PBrBr), the second being axillary. Three to four secundibrachials (SBrBr), have been observed without further bifurcation or evidence of free arms. Intersecundibrachials (ISBrBr) are present and may consist of one followed by one, or one followed by two. Median rays originate on the basal plates and converge on the radial plates, forming a star having apices which alternate with those of the basal circlet. These ridges pass onto the brachials and mark the rays to their termination. In addition there is occasionally a light ridge starting in mid-portion of r. post. R and forming a ray on the plates in the right portion of the posterior interradius. This is especially true of large specimens from the Spring Creek locality and might represent a divergency of subspecific stature.

Each IR is followed by two interbrachials (IBrBr) with the exception of the posterior interray. Above the first IBrBr there is normally the arrangement 3-4-4. In the posterior interray, X is followed by either two or three anal plates, and the next series above has four plates, as compared to three plates in other interrays. The posterior interray is usually wider than other interrays and is inclined to protrude. In well preserved specimens, one may observe faint ridges passing from each basal plate onto the interradial from whence they diverge to the right and left IBrBr. These rays are considered by this author to represent a tendency toward the formation of divergent ridges (with intervening depressions) connecting all cup plates which condition is often found in other representatives of the genus.

When the column is present, the IBB are entirely covered by the proximal columnals. Columnals are wide, thin, alternatingly expanded. Although having a circular outline there are actually numerous short, flattened facets on the outer surfaces. The lumen is large and more or less circular in outline. A narrow ridge, which is decidedly crenulated, surrounds the lumen.

The tegmen and arms are unknown. Sporadic nodes are found on some specimens, but no definite surface ornamentation has been observed other than previously mentioned rays.

Measurements in mm.—

	Smallest observed paratype	*Largest observed paratype*	*Holotype*
Height of dorsal cup	19.0	36.2	22.6
Max. width of dorsal cup	14.5	46.0	28.8
Width of basal depression	4.2	7.8	5.4

Remarks.—There is some variation between specimens found at slightly different horizons, mainly in the greater or lesser tumidity of the dorsal cup. Lack of surface ornamentation, regularity of plates in the interradius areas, the shape of dorsal cup, and the relative width of basal depression as compared to the width of dorsal cup, are distinctive and serve to distinguish *A. subovalis* from other known species.

Types.—Holotype, paratypes and numerous metatypes are to be deposited in the U. S. National Museum.

CONCERNING THE MICROFAUNA FROM PEÑON SEEP, MATANZAS PROVINCE, CUBA[1]

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IN AN article entitled "Middle Eocene Foraminifera from Peñon Seep, Matanzas Province, Cuba," W. S. Cole and D. W. Gravell (1952) present a table (p. 710) showing the local names introduced by Applin and Applin (1944, pp. 1686–1703; table 1) for subsurface stratigraphic units that they recognize in the limestone facies of the Eocene rocks on the Florida peninsula. In connection with these different Eocene units, Cole and Gravell's table names 11 foraminiferal species, which they designate "key fossils," "selected from lists given by Applin and Jordan (1945) to match the species present at Peñon Seep." The faunal assemblage lists referred to were published by Applin and Jordan (1945, pp. 129–132) under the caption "List of common and characteristic species of Foraminifera in Florida formations." The term "key fossil" connotes a species that is confined to the stratigraphic unit from which it is recorded, but Applin and Jordan's designation of the Foraminifera as "common and characteristic," on the contrary, does not preclude the possibility that an occasional species may range through more than one unit, and we believe that the assemblage lists have, in large measure, proved useful as a guide to the identification of stratigraphic units in the Florida subsurface.

Immediately following their table of "key fossils," Cole and Gravell state: "Of the 16 previously named species considered at Peñon Seep, 11 occur in Florida, and accord-

[1] Publication authorized by the Director, U. S. Geological Survey.

TABLE 1

Previously named species recognized from Peñon Seep (Cole and Gravell, 1952, p. 709)	Stratigraphic distribution in Cuba as recorded by Pedro J. Bermudez (1950, pp. 326–327)					Stratigraphic distribution in Florida as recorded by Applin and Jordan (1945, pp. 130–131)
	EOCENO					
	Superior		Medio	Inferior		
	Consuelo	Jabaco-Jicotea	Loma Candela	Universidad	Capdev. Lucero	
Amphistegina lopeztrigoi Palmer	.....	.....	————	————	————	Lake City (early middle Eocene)
Asterocyclina habanensis Cole and Bermudez	.....	.....	.....	.....	————	..... not recorded
Asterocyclina monticellensis Cole and Ponton	.....	————	.....	.....	.....	Lake City (early middle Eocene)
Cribrotextularia coryensis (Cole)	.....	..... not recorded		.....	.....	Avon Park (late middle Eocene)
Dictyoconus americanus (Cushman)	.....	————	————	.....	————	Lake City (early middle Eocene)
Dictyoconus cookei (Moberg)	.....	.....	————	.....	.....	Avon Park (late middle Eocene)
Discocyclina (Discocyclina) marginata (Cushman)	.....	————	.....	.....	.....	..... not recorded
Discorinopsis gunteri Cole	.....	..... not recorded		.....	.....	Avon Park (late middle Eocene)
Eoconuloides wellsi Cole and Bermudez	.....	.....	————	.....	————	..... not recorded
Fabiania cubensis (Cushman and Bermudez)	.....	————	————	.....	.....	Lake City (early middle Eocene)
Gunteria floridana Cushman and Ponton	.....	————	————	.....	.....	Lake City (early middle Eocene)
Helicostegina gyralis Barker and Grimsdale	.....	.....	————	————	————	Oldsmar (lower Eocene)
Pseudophragmina (Proporocyclina) cushmani (Vaughan)	.....	.....	.....	.....	————	..... not recorded
Pseudophragmina (Proporocyclina) psila (Woodring)	.....	..... not recorded		.....	.....	..... not recorded
Spirolina coryensis Cole	.....	..... not recorded		.....	.....	Avon Park (late middle Eocene)
Valvulina martii Cushman and Bermudez	.....	.....	————	.....	.....	Avon Park (late middle Eocene)

ing to Applin and Jordan range from lower Eocene to late middle Eocene." The meaning of the quoted sentence is obscure but it is apparently a misstatement, for Applin and Jordan did not say that the 11 species, or any of them, "range from lower Eocene to late middle Eocene." Of five species "selected" from the 14 recorded by Applin and Jordan from the Avon Park limestone (late middle Eocene), a varietal form of one species, *Discorinopsis gunteri* Cole, is fairly common in the underlying Lake City limestone (early middle Eocene). So far as we are aware, all the "selected species" from the Lake City limestone are confined to that unit. Applin and Applin (1944, p. 1699) chose *Helicostegina gyralis* Barker and Grimsdale as the key fossil of the top zone (Zone I) of the Oldsmar limestone (lower Eocene) and pointed out (p. 1693) that the "faunal zone at the top of the lower Eocene may eventually be proved to be Mount Selman in age."

According to Cole and Gravell (p. 710), "It would appear that the 6 inch bed at Peñon Seep contains many of the key fossils by which three or four formations in Florida are recognized." They matched the species recorded from Peñon Seep with Eocene species in Florida but did not make the equally appropriate comparison between the Peñon Seep species and those recorded from formations of Eocene age in Cuba. The tabulation on page 607 shows: (1) the 16 previously named species recognized from Peñon Seep (Cole and Gravell, 1952, p. 709); (2) the stratigraphic distribution in Cuba of each of the 16 species as recorded by Bermudez (1950, pp. 326–367) in his list containing 1,511 species and varieties of Cenozoic Foraminifera; and (3) the stratigraphic distribution in Florida of each of the 16 species as recorded by Applin and Jordan (1945, pp. 130–131).

Cole and Gravell record 22 species from Peñon Seep, 10 of which are new or not shown in Bermudez's list of Cenozoic Foraminifera; the tabulation below shows that 12 species occur in one or more of four formations of Eocene age in Cuba.

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NOTES ON FORENSIC PALEONTOLOGY

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My esteemed colleague and flatterer, Carl C. Branson, has suggested in the November issue of the *Journal* that all new names proposed in this *Journal* should be accompanied by etymologies, and has presented a case which seems to have convinced the editors. I would like to comment on this proposal, with which I cannot agree.

May I preface my comments with some general statements of belief. Paleontology is the study of fossils, not the study of the names of fossils. Time spent in consideration of nomenclature is time wasted, and the waste can only be justified if the end result is that less and less time need be so spent. Those rules are good which permit least argument. Those rules are bad which invite discussion.

Applying these principles to the naming of fossils, I would suggest that the only rule permitting objective, unambiguous, unanimous usage is this: the name of an animal shall be that combination of letters first proposed as its name. Period. This no matter how uncouth, how misbegotten, how inappropriate this name may be. This is the only name about which there can be no argument, for all can read it in the original description

and then go ahead and use it. Were I rewriting the *Règles* I would delete Articles 13, 14, 15, 16, 19 and 20, and replace them with the single sentence, "A trivial name shall be one word in classical form, in agreement with the generic name if it be an adjective." The other material in these Articles is commentary and suggestions on matters of taste, which should have no place in a set of rules.

But I have not yet been invited to reframe the *Règles*, and we must work within those we have, including Article 19, which says that if certain kinds of errors are obvious in a name, then it must be changed. This brings us back to etymologies, for if no derivation is given in the original paper, then no improper formation can ever be obvious, and thus no name can be changed. The minute you state what you think your name means, you invite the tinkers and meddlers and aesthetic theorists to remake your name into a better one. I know there are clairvoyants who do not agree with this analysis, but I am prepared to invent spaniels as often as may be necessary to emphasize the complete subjectivity of guesses in the absence of stated derivations.

In Branson's paper we have examples of the sort of thing I wish to avoid. He begins with the completely laudable view that names should mean something, and so far I agree with him heartily, but he goes on to say that if a name does not mean something it should be changed until it does. Thus he takes the meaningless name *Isalaux* and decides (on the presumption that it must mean something) that it should be *Isaulax*, and so emends it. Now Branson's reasoning may be completely sound, and the authors may have intended to write *Isaulax*, but there is absolutely nothing to suggest that in the original paper, and this interpretation is entirely subjective. Must I invent a gopher?

The snares laid when derivations *are* given are illustrated by Branson's example *Mesophyllum pueranum*. As it stands this is a pretty good name; it is short, it is pronounceable, it looks like Latin. But the authors have told us that the name is derived from the province in which the specimens were found, and in their introduction say that the locality is in the "Department of Piura." Branson feels that this necessitates a change of the name to *M. piuranum*. I do not see that this follows as an obvious consequence of the data. I would want to know a number of things. In Peru are provinces and departments identical? Can the Department of Piura be in a Province of Puera, or can it contain a Province of Puera? If there is no such thing as a Province of Puera, and "province" in the description is to be interpreted as "department" it still is not obvious that the given name is wrong. Is the name Piura in some way a cognate of the Latin *puer*, so that authors wishing to base a name on the locality could so latinize the Peruvian name? These are all questions to which I could get answers. I could search atlases, write colleagues in Peru, delve into histories to see who named Piura and why, and at the end of all this dusty labor I would have the "right" name for this species of coral. But at what a cost! Surely it would be much simpler to say: These authors have named a coral *Mesophyllum pueranum*, so be it.

These are matters which I have discussed, in part, elsewhere, and I refer those interested to my paper on "Emendation of Zoological Names" (American Midland Naturalist, 46: 252–254, 1951).

If the editors of the *Journal of Paleontology* are agreed that great good will result from compulsory publication of derivations, then let it be done in such a way as to avoid any possibility of emendation. Let them set aside a page at the back of each number to be headed "Etymology of new names proposed in the last issue of this *Journal*." Then we will know what names were planned to mean, and the papers themselves will be kept free of anything which could afford an excuse to name-changers.

Better still, in my opinion, let the editors leave such matters of taste unlegislated.

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NOMENCLATURAL NOTES

NOMENCLATURE OF CONODONT ASSEMBLAGES

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The recent interesting note in this *Journal* (1953, pp. 489–490) by Dr. G. Winston Sinclair on the naming of conodont assemblages (of which he kindly sent the present writer an advance copy) raises a number of important considerations which seem to merit further discussion.

Dr. Sinclair's main suggestion was that conodont assemblages should be named after the first component conodont of the assemblage discovered. Thus he suggested, for example, that the assemblage described by Rhodes as *Scottella typica*, comprising representatives of the conodont "form-genera" *Idiognathodus* or *Streptognathodus*, *Ozarkodina*, *Hindeodella* and *Synprioniodina* should more correctly be named *Streptognathodus elegantulus* (after one of its conodont components). Dr. Sinclair further suggested that each component conodont of such an assemblage should be described by an adjective (derived from its generic name) and should be noted as being an element of a particular assemblage (e.g., "the subbryantod element of *Streptognathodus elegantulus*" (Sinclair, p. 489).

This method of nomenclature is one to which the present writer gave very careful consideration before his recent article was published. There seemed, however, to be several difficulties involved, which, in spite of certain advantages in the method, would have resulted in considerable confusion if it had been applied to the conodont assemblages in question. It should be emphasized that these problems are, on the whole, peculiar to the study of conodonts and scolecodonts and do not arise in the case of other groups. It is, therefore, a little misleading to draw analogies with the classification of other animals.

The difficulties encountered in attempting to apply Dr. Sinclair's method of nomenclature may be summarized under three main headings.

1. The name to be used for the assemblage.

Dr. Sinclair suggests "that in all such cases the proper name is that given to the *first-named* part of the animal" (p. 490, the italics are mine). This therefore means that, in the case of a conodont assemblage where as many as five "form-genera" may be present, we should select the name of the first described genus as being applicable to the assemblage. There are, however, three serious objections to this.

a. This "first-named" genus may not *always* be present in the assemblage to which its name is given. This is well illustrated in the name *Streptognathodus*, which Dr. Sinclair suggests should be substituted for the name *Scottella*.[1] It has been shown (Rhodes, 1952, p. 892) that the polygnathid element of this assemblage may belong to either *Streptognathodus* or *Idiognathodus*. It therefore appears misleading and unjustifiable to apply this generic name to assemblages in which it does not occur. The assemblages containing *Idiognathodus* cannot, however, be separated from those containing *Streptognathodus*, since polygnathid components are present which completely bridge the gap between the two genera.

b. The second difficulty arises from the fact that a single "form-genus" may be present in very different types of assemblage. It has been noted that, if the name of the first described genus is given to *Scottella*, the name would have to be either *Hindeodella* or *Lonchodina*. *Hindeodella*, however, is present in three types of assemblage (*Lewistownella*, *Lochriea* and *Scottella*), which are so markedly different in their other components

[1] Actually, *Streptognathodus* is not the first described genus of the assemblage. *Lonchodina* and *Hindeodella* were both described by Ulrich and Bassler in 1926. If Dr. Sinclair's suggestion is accepted, the assemblage should be named after one of these latter genera.

that conodont workers have named them as distinct genera. If these were all named after *Hindeodella*, the result would be the "lumping" of these three fundamentally different forms into a single genus. Similarly, *Lonchodina* is present in the strikingly different assemblages *Duboisella* and *Illinella*.

It may be argued that, in such a case, the name of a "form-genus" unique to the particular assemblage should be used. It is, however, quite impossible to predict whether or not a "form-genus" will be confined to a particular type of assemblage. No name of a "form-genus" can therefore be used without the risk of its subsequently being found to be present in another fundamentally different type of assemblage.

c. The same problems apply in the selection of the specific name. Dr. Sinclair does not make it clear how this name is to be chosen. It appears (p. 489) that he may choose the type species if this is present in the assemblage. Thus he selects *Metalonchodina bidentata* but does not however, select the trivial name of the type species of *Streptognathodus*, although it is present in the assemblage. Whichever name is selected, the problems discussed above in paragraphs *a* and *b* remain.

2. The name to be used for individual components of an assemblage.

The suggestion that the component "conodonts recognized . . . in . . . assemblages would drop their given names . . . and e.g. the conodonts hitherto known as *Ozarkodina delicatula* would be referred to as the subbryantod element of *Streptognathodus elegantulus*" (Sinclair, p. 489) would result in utter confusion in the nomenclature of the individual conodonts, which are so useful in stratigraphical studies. It so happens that this particular element is not variable within assemblages of "*Streptognathodus elegantulus*" (Dr. Sinclair's terminology) and would therefore be adequately designated by this method. In the case of other component "form-genera," however, variation in form is considerable, and a "specific" qualification would be necessary in order to designate any particular form (e.g., the subbryantod type A element of *Streptognathodus elegantulus*, using Dr. Sinclair's terminology). This would necessitate a complete revision of conodont terminology and would involve the substitution of a clumsy and less satisfactory system of nomenclature than that in current usage.

3. Precedents established by earlier workers and current nomenclatural usage.

Schmidt (1934) followed the method of naming suggested by Dr. Sinclair. He named a natural assemblage *Gnathodus integer*, after a component "form-genus," although the trivial name was new. This assemblage included a number of "form-genera," which should subsequently have been regarded as synonyms of *Gnathodus*. Reference to subsequent literature suggests that this synonymy has been completely ignored by later workers, who have continued to use the older generic names.

It must also be borne in mind that conodont assemblages are only very rarely found and that considerable time will be required to determine the relationships of existing "form-genera and species." Apart from other considerations it would appear most undesirable to introduce the proposed unwieldy system of nomenclature for a relatively few genera, when the majority of specimens must still be named as individual "form-genera and species." This aspect of the problem has been ably discussed by Hass (1941, p. 80) and Scott (1942, p. 295), both of whom favor the preservation of the existing nomenclature.

Scott (1942) has created a precedent by giving new names to conodont assemblages, thus leaving existing "form-genera and species" undisturbed. This method of nomenclature appears to have been well received by conodont workers. Although the present discussion is concerned with conodonts, an exact parallel is found in the classification of scolecodont assemblages. In his recent outstanding contribution, Lange (1949, pp. 15, 53) gave a new name to the assemblages he described and included within the new genus the many component "form-genera and species" previously named.

It therefore appears to the present author that the foregoing difficulties make Dr. Sinclair's suggested method of nomenclature, while perhaps theoretically preferable, one which cannot satisfactorily be applied in practice.

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FOOTNOTE ON A CORRECTION OF THE NAME "*Scottella*"

Dr. Hans E. Thalmann has kindly informed the present author that the name "*Scottella*" (proposed for a conodont assemblage) is preoccupied by a dipteran [*Scottella* Enderlein, 1910, Trans. Linn. Soc. London, (2), Zool., 14, 60]. The name "*Scottognathus*" (type species: *Scottognathus typicus* Rhodes) is therefore proposed to replace "*Scottella*," (Rhodes, 1952, A classification of Pennsylvanian conodont assemblages: Jour. Paleontology, vol. 26, p. 890).

Further study of Schmidt's illustrations of conodont assemblages (1933) leads the present author to believe that Schmidt was correct in identifying the polygnathid elements as *Gnathodus* (Rhodes, 1952, p. 890). This means that Schmidt's "natural genus" *Gnathodus* is not con-generic with *Scottognathus* (Rhodes, 1952, p. 890). The question of the name to be used for the assemblages described by Schmit involves the problems discussed above, since the name "*Gnathodus*" is at present used in two quite different senses by conodont workers. If the present author's suggestions are accepted, a new name should be given to Schmidt's "natural-genus" and the name "*Gnathodus*" be restricted to the "form-genus"described by Pander.

JOURNAL OF PALEONTOLOGY, VOL. 27, NO. 4, PP. 613–614, JULY 1953

BOOK REVIEWS

PALEONTOLOGY AND MODERN BIOLOGY. Watson, D. M. S., Yale University Press, p. 216, fig. 77, 1951.

Dr. D. M. S. Watson, Professor Emeritus of Zoology and Comparative Anatomy, University of London, presented the Silliman Memorial Lectures at Yale University in 1937. His wartime duties delayed the completion of the manuscript, but appendixes to each chapter include appropriate material to bring it to date.

The book has a somewhat ambitious title not wholly warranted by the contents. The reader will not find any treatment of micropaleontology nor invertebrate paleontology. Professor Watson's general paleontology beyond the simple principles covers only the lower classes of vertebrates, and that in such detail that unless one is familiar with the genera and thoroughly conversant with skull morphology it would probably make hard reading.

Professor Watson very ably and at times brilliantly discusses the origin of true jaws, evolution of one group of amphibians, origin of reptiles and the origin of the mammalian ear. He presents a new interpretation of the derivation of the mammalian ear bones which is most valuable.

Professor Watson's modern biology at times does not seem so modern. He argues for the intellectual respectability of procedures in morphology which is brought about by the verification of predictions, but certainly not all of the "most extended flights of morphologized argument have led to predictions which, within the past few years, and very unexpectedly, have been verified by the description of actual fossil animals whose structure conforms exactly to expectation." Accurate morphologized description, and perhaps prediction too, have always been respectable intellectual pursuits, and even though it is somewhat out of style in some circles, there is still more yet to be done than that which is already completed.

To lift paragraphs out of context is often unfair, but the following quotation is repeated many times and is not particularly revised in any of the appendixes.

> In the case of the amphibia these fundamental changes, on which the more obvious structural modifications are consequential, are very few in number, only two being well established, and are of a kind for which no adaptive explanation seems possible. They appear to depend on secular internal factors whose nature is entirely unknown.

Few modern biologists would accept such interpretations as would few modern vertebrate paleontologists.

The great contributions Professor Watson has presented are his keen observations on the relation of form and function. His knowledge of the lower vertebrate faunas of Russia, South Africa and North America has enabled him to interpret and synthesize much unpublished morphological data and that found only in obscure journals.

JOHN A. WILSON
University of Texas

STUDIES OF ORGANIC LIMESTONES AND LIMESTONE-BUILDING ORGANISMS. Compiled by J. Harlan Johnson, Quarterly of the Colorado School of Mines, vol. 47, no. 2, 1952, 94 pp., 1 figure, 26 plates, 9 tables. $1.50.

This compilation consists of four separate articles. In the first, "The Shell Structure of the Modern Molluscs," I. H. Mackay describes thin sections of the shell material of 22 species from 12 genera of gastropods, and 5 species from 5 genera of pelecypods. The author assumes that different environments, habits, and growth of animals should develop varied shell structure and that these differences might be characteristic of various animal groups. Homogeneous, prismatic, cross-lamellar and nacreous types of shell structure were observed. These are well illustrated in a number of photomicrographs. Though the study was somewhat limited quantitatively, especially among the pelecypods, there appears to be a definite correlation between the arrangement and particular combination of the shell layers and the individual molluscan genus.

In the second article, "Ordovician Rock-Building Algae," J. Harlan Johnson gives a brief summary of our knowledge of Ordo-

vician algae. He considers 4 classes, 5 families, 16 genera and 67 species. The 12 plates, containing 47 figures, represent an important compilation. These, together with the descriptive data, are sufficient to distinguish the more important algal forms. This article is a welcome addition to the rather meager literature on a complex, often neglected group of organisms.

In the third article, "Organic Limestones of the Middle and Lower Pennsylvanian of Kansas," W. Lebsack has made a descriptive study, megascopically and microscopically, of 10 limestone formations in the Lansing, Kansas City, Bronson, and Marmaton groups, from 18 localities in eastern Kansas. The limestones are marine and occur in cyclic alternations with shales. Fifty thin sections are studied and the organic content noted as to relative abundance and associations. The relative abundance noted is as follows: 1. algae, 2. Bryozoa, 3. crinoids, 4. corals, 5. Foraminifera, 6. brachiopods, 7. echinoids, 8. molluscs. In general the greatest concentration of the organisms is in the top and bottom members of a limestone formation. The associations appear somewhat random, with the possible exception of Bryozoa and Foraminifera which are found together in over half of the thin sections. It is questioned whether this is an environmental association or possibly due to their better preservation in recrystallized limestone.

In the last article "Pennsylvanian Reef Limestone, Terry County, Texas," R. H. J. Elliott and O. J. Kim report on the results of a megascopic and microscopic study of 141 feet of core samples from the Canyon limestone near the north end of the Midland Basin. Twenty-five thin sections from this thickness are studied in detail to interpret the environment of deposition of the reef limestone. The principal organisms present include Foraminifera, corals, echinoderms, Bryozoa, brachiopods, molluscs, and calcareous algae. The important rock types include calcarenites (clastic and allochthonous) and calcilutites and some questionable autochthonous algal limestone. The writers recognize that since the thin sections were made at five-foot intervals that considerable interpolation is necessary in drawing conclusions. Also data from a single well restrict conclusions concerning the lateral variations and shape of the reef limestone. However, from the known areal geology of the region together with the data from the section studied, the authors assume the section to be a part of a shoal reef developed in a bank-reef type environment.

C. E. PROUTY
University of Pittsburgh

NOTICE

UNITED STATES GOVERNMENT AWARDS UNDER THE FULBRIGHT ACT, 1954–55

Public Law 584—79th Congress—Under Auspices of Department of State and Board of Foreign scholarships.

UNIVERSITY LECTURING—ADVANCED RESEARCH: Austria, Belgium and Luxembourg, Denmark, Egypt, Finland, France, Germany, Greece, Iraq, Italy, Japan, Netherlands, Norway, Pakistan, Sweden, United Kingdom and Colonial Dependencies.

Application forms and additional information obtainable from

CONFERENCE BOARD OF ASSOCIATED RESEARCH COUNCILS
COMMITTEE ON INTERNATIONAL EXCHANGE OF PERSONS
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This competition is specifically for university lecturing and postdoctoral-level research. Graduate students desiring to enroll for courses abroad or to pursue a direct program of studies at the predoctoral level should apply to their local Fulbright Adviser or directly to the Institute of International Education, 1 East 67th Street, New York City.

Applications for university lecturing and advanced research must be postmarked no later than October 15, 1953.

JOURNAL OF PALEONTOLOGY, VOL. 27, NO. 4, PP. 615–618, 1 TEXT FIG., JULY 1953

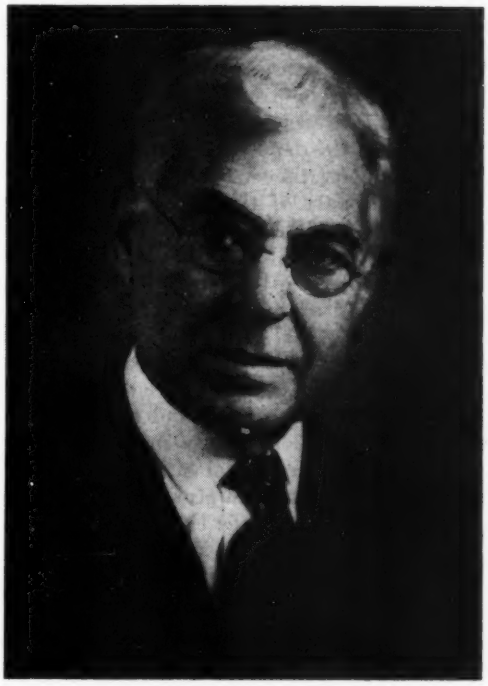
MEMORIAL

GILBERT DENNISON HARRIS
1864–1952

GILBERT DENNISON HARRIS, one of the leading exponents of Tertiary paleontology and stratigraphy in America, died at his home, 126 Kelvin Place, Ithaca, New York, on December 4, 1952. He was born near Jamestown, New York, on October 2, 1864, the son of Francis E. and Lydia H. Crandall Harris. His brother, the late Rollin Arthur Harris (1863–1918), was the author of the monumental "Manual of Tides" and mathematical designer of the then new and most satisfactory tide-predicting machine.

Harris went to high school in Jamestown, New York, and graduated from Cornell University with the class of 1886. In that same class were Robert T. Hill and David White, all of whom became geologists of the same high caliber. It is interesting to note the answer of each of the three scholars to the questionnaire of the class of '86 as to their "Future occupation." Hill put down "man and science," White responded, "naturalist," and Harris replied, "undecided." He had taken a general course which led to the degree of Bachelor of Philosophy (Ph.B.), and it was the purchase and reading of Dana's "Manual of Geology" which effected the decision as to his professional choice. In the Fourth Edition (1895) of that same great compendium of earth science, Harris wrote the description of the marine Tertiary of North America, illustrated by many drawings from his own pen. With the exception of Timothy W. Stanton (now 93), G. D. Harris was the last of the collaborators with Dana on that classic.

After a year of graduate work under Henry Shaler Williams at Cornell, associated with Charles S. Prosser, he joined the Arkansas Geological Survey in 1888. John C. Branner (botanist-geologist) was State Geologist and Frederick W. Simonds an assistant; both had been trained by Charles F. Hartt who initiated so brilliantly geological work at Cornell.



GILBERT DENNISON HARRIS
1864–1952

By means of cooperation between the United States Geological Survey and the Arkansas Geological Survey, R. T. Hill, who preceded Harris, had been assigned the task of delineating the history and extent of the Cretaceous of Arkansas. In the same manner, Harris (1891–92) was delegated a similar assignment for the Tertiary.

The rigors of the physical conditions under which the work of the early Arkansas Survey was done had ill effects on Harris physically and left a lasting impression as to the care and conditions under which geologists should work. Some of the less hardy neophytes did not survive.

The results of the field work in 1891–92 on the Tertiary of Arkansas as published

(1893) by Harris in Volume II of the Annual Report of the Arkansas Geological Survey for 1892 emphasized new facts: that (1) the Cretaceous extended farther to the northeast than formerly supposed; (2) Arkadelphia shales previously called Tertiary were Cretaceous; (3) that beds in Pulaski County containing "*Enclimatoceras*" *ulrichi* White (*Hercoglossa ulrichi*) referred to the Cretaceous were Eocene; (4) that the oldest Tertiary in Arkansas was Midway, a stage which should be treated as of coordinate rank with the "Lignitic" [Sabine (Wilcox)]. He referred the deposits of the classic White Bluff beds on the Arkansas River to the uppermost part of the "Claiborne stage," noting the existence of characteristic Jackson species of mollusks. The sediments are now regarded as Jackson Eocene. Harris did not return to the Arkansas Tertiary section until 1937 where on Crow Creek near Forrest City, he discovered a vertebra of *Basilosaurus cetoides* (Owen), the only zeuglodont bone so far found in Arkansas.

From 1889–92 he was a member of the United States Geological Survey associated with the Smithsonian Institution as assistant to William H. Dall. During that period, the foundation was laid for his reputation and long career as "Dean of the Gulf Coast stratigraphers." His basic experiences included: the study of the store of Gulf Tertiary fossils of the United States Geological Survey and the Academy of Natural Sciences of Philadelphia; the field work in the "winter of 1891–92" on the lower Tertiary of Arkansas; the writing (1890–91) with Dall of the Neocene Correlation Papers of the United States; measuring the sections and collecting with that prodigious fossil gleaner, Frank Burns, from the Calvert Cliffs, Maryland; work of two seasons (1892–Feb. 1893) in Texas on the Texas Geological Survey under E. T. Dumble including the preparation of a 392-page and 34-plate manuscript on the Tertiary of Texas; and the reprinting (April, 1893) of T. A. Conrad's "Fossil shells of the Tertiary formations of North America." Lack of funds prevented the Texas Tertiary report being published as it was originally planned in the 5th Annual Report of the Texas Survey. The plates were composed of fine drawings by Harris and that skilled artist, Dr. J. C. McConnell of Washington, D.C. The new species described by Harris in that manuscript were later (1895) published in the Proceedings of the Academy of Natural Sciences of Philadelphia. In the winter term of 1926–27, Professor Harris returned to the University of Texas as Visiting Professor of Paleontological Geology in the Graduate School.

In the 1890's, none felt the lack of the original fundamental Tertiary paleontologic works of Conrad, Lea, and Gabb more than an earnest, ambitious student such as G. D. Harris. The most difficult to obtain then, as now, were the privately printed papers of Conrad. In 1893, Harris wrote, "He who would become versed in the marine Tertiary geology and paleontology of this country must first of all have a thorough understanding of Conrad's FOSSIL SHELLS OF THE TERTIARY FORMATIONS OF NORTH AMERICA; it marks the beginning of systematic research into this period of our continent's history." The result of comparing notes on the 16 existing 1893 original copies of Conrad's Fossil Shells was that Harris negotiated the reprint of 225 copies of the book with 200 copies of the plates reproduced by the Albertype method. The success of this venture and the satisfaction derived from the enterprise stimulated him later to found the publication of two series of paleontologic works, one of these included the republication of the paleontological writings of Thomas Say (1819–1825) in 1896, of Robert John Lechmere Guppy (1865–1913) in 1921 and Conrad's Jackson Eocene fossils (1854) in 1939. The last was under the auspices of the Paleontological Research Institution.

In 1894 Gilbert Harris was invited to join the faculty of Cornell University. For additional preparation for such a teaching position, he went to France and England to familiarize himself with the type areas of the Eocene and make first hand collections. For 41 years, Harris taught paleontology and stratigraphic geology at Cornell University. He went to Cornell as Assistant Professor; became Professor in 1909 and retired as Emeritus on October 2, 1934, his 70th birthday.

Professor Harris's philosophy of teaching is best defined by himself in his report (1900)

to the President of Cornell University, "From the lessons of our own experiences, as well as from the lives of others, we are led irresistibly to the conclusion that the most natural way of acquiring a knowledge of the earth is to be associated in Nature's laboratory—the field—with some experienced person who is carrying on original investigations."

This principle Harris carried out in his direction of students. Though it, like that of the great Agassiz, did not result in mass production, his technique developed outstanding geologists and paleontologists who returned to their teacher and the science, the devotion and loyalty which he had inspired. He was not a clear or appealing lecturer so that it was through direct contact with students that he gained a lasting confidence. He ever sent or took his students into the field by ways or means expedient to the time. In 1895–96 he and students investigated and collected fossils in the southern states. In 1897–1909 he transported summer classes in his two gasoline launches, the *Orthoceras* and *Ianthina* to the Helderbergs, Hudson River, and the Lake Champlain regions via the Erie and the Champlain canals and explored the banks of Cayuga Lake. In 1914–15 his *Ecphora* carried a boatload of students to the Chesapeake Bay and until 1920 the same boat took the students in Historic Geology at Cornell to the abundantly fossiliferous localities in the Hamilton Devonian along Cayuga Lake.

While teaching at Cornell, he served as geologist-in-charge to the Geological Survey of Louisiana (1898–1909). With the enthusiastic and able assistance of A. C. Veatch and J. A. A. Pacheco, together with many others of his students, in the field and laboratory, and with the cooperation of the U. S. Coast and Geodetic Survey, he produced the Louisiana Geological Survey reports of 1899, 1902, 1905, 1907, 1908, and 1909. These mark an important period of investigation of the Mississippi Embayment area. Besides surface deposits, underground waters, salines, and the practical use of paleontology, special emphasis was placed on precise measurements which are fundamental to geologic structural interpretation. The pioneer establishment of magnetic stations, meridian lines, self-recording tide gage and bench marks set a standard, the value of which more highly technical instruments and advanced accumulated geologic information cannot lessen.

His knowledge of the Louisiana domes and his published reports on oil and gas in Louisiana (1910) and on salt (1908) which included his theory of salt domes was still regarded (1926) as the "most complete general descriptions of American salt domes." His discovery of the Sabine Uplift of northwestern Louisiana and northeastern Texas was a major contribution to the study of the structural history of the Gulf area.

In 1895, Professor Harris founded the BULLETINS OF AMERICAN PALEONTOLOGY (octavo) and in 1917 PALAEONTOGRAPHICA AMERICANA (monographs in quarto). The latter is subtitled, "Illustrated Contributions to the Invertebrate Paleontology of America." Such a heading is applicable to the Bulletins as well. Each series included papers on vertebrate fossils. Emphasis was placed by Harris in both publications on extensive figuring of fossils. Besides being writer, publisher, editor, and printer on his own presses, Harris skillfully made drawings for the early Bulletins, later photographed fossils superbly, and for a few numbers experimented with collotype engraving.

One of his chief plans in the publications, which resulted from the detailed field work and a large accumulation of fossils, was to write a series of successive, thoroughly illustrated monographs of the fossils of the southern Tertiaries. That standard list includes the Midway [Paleocene] (Bull. 4, 1896), the Lignitic [(Wilcox) Sabine] (Bull. 9, 1897; 11, 1899), Claiborne (lower and Gosport sand) (Bull. 31, 1919, Harris, and 32, 1937, Palmer) and Jackson (Bull. 117, 1946, 1947, Harris and Palmer). Consultation on South American geology in 1921–25 with the extensive collecting of fossils and the promotion of students into geologic work in the Caribbean and Southern Hemisphere inspired a long series of publications in the Bulletins on the paleontology and stratigraphy of that region.

To house properly a large and an increasing collection of paleontological types, publication stock, and library and to provide for the perpetuation of the scientific endeavors

so daringly begun, Harris founded in 1932 the Paleontological Research Institution which was chartered by the State of New York. He gave a portion of his home lot, a building, two publication series, library and equipment to the institution. Until 1952 he guided its destiny. He continued to operate his presses and by 1949, in his 85th year, he had printed through No. 134 of the Bulletins of American Paleontology. His failing eyesight became a handicap but until his last illness he spent long hours in photographing and compiling data on his favorite family of gastropods, the Turridae.

Harris was a member of Phi Beta Kappa, Sigma Xi, Sigma Gamma Epsilon, Société Géologique de France, the Eclogae Geologicae Helvetiae, Fellow of the Geological Society of America and the Paleontological Society of America, Honorary Member of the American Association of Petroleum Geologists, and Corresponding Member of the Academy of Natural Sciences of Philadelphia. He was elected President of the Paleontological Society of America in 1936 and the following year, Vice-President of the Geological Society of America. Founder of the Paleontological Research Institution, he served as Life Trustee, Treasurer 1932–1951 and Director, 1950–1951.

In 1890 Gilbert Harris married Clara Stoneman of Chautauqua County, New York. She was a wise and beloved companion and her death in 1932 was a great blow to Professor Harris. Their daughter, Rebecca Stoneman Harris, resides at the home in Ithaca. Miss Florence B. Harris, a surviving sister, lives in Falconer, New York.

Gilbert Dennison Harris was a tireless worker mentally and physically. He was interested in politics and world affairs, but his alert mind was chiefly concerned in developing geologic science, particularly paleontology. His predominant scientific activities and interests were balanced with a wholesome sense of humor. He was modest of his own worth but lavish in praise of those he thought deserved commendation. He had no interest for the students who were indifferent but for those who were capable and energetic, he continually thought to provide opportunities for their training. Through his basic efforts of original personal field studies and research, through his training of students who also contributed to geologic investigations, through the original establishment of the series of fundamental paleontological literature and the founding of an institution for the collection, preservation and dissemination of paleontologic material, G. D. Harris can be said to be one of the high priests in the science of paleontology and stratigraphy in the Western Hemisphere.

KATHERINE V. W. PALMER
Paleontological Research Institution
Ithaca, New York
May 28, 1953

LOUIS JOSEPH WILBERT, JR.
(1919–1953)

When I was a lad I served a term
As office boy to an Attorney's firm.
I cleaned the windows and I swept the floor,
And I polished up the handle of the big front door.
I polished up that handle so carefullee
That now I am the Ruler of the Queen's Navee![1]

LOUIS JOSEPH WILBERT, JR., scientist, educator and consulting geologist, died near noon, March 17, 1953, as a result of injuries sustained in an automobile accident that morning near Opelousas, Louisiana. A memorial as this can pay only partial tribute to the capability, integrity, vitality and inspirational ability of Slick, as he was known to all his friends. Nor can such a commentary possibly ascribe the great personal and professional losses we have all suffered by his untimely departure on the threshold of a brilliant scientific career.

Louis was born in Plaquemine, Louisiana, October 21, 1919, the eldest child of Louis Joseph and Gertrude Pope Wilbert. He attended Plaquemine secondary schools, and, at this early stage, gave evidence of the capacities for study and achievement for which he was later so well known, by being salutatorian and valedictorian of his elementary and high school classes respectively. At the same time, he was a student leader, participated actively in athletics, and attained the rank of Eagle Scout. His first major achievement was the winning of a $25.00 gold prize for the best essay on American History by a seventh-grade student.

After completion of his high school requirements in 1936, he entered Spring Hill College operated by the Jesuit Order in Mobile, Alabama. Until this time he had been undecided as to a career, but during his year at Spring Hill he settled upon geology. Realizing that he could not obtain the necessary training for professional competence in this field at Spring Hill, he matriculated at Louisiana State University in the fall of 1937 to work toward the B.S. in geology. Here he formed the associations with H. V. Howe

[1] Gilbert and Sullivan, *H.M.S. Pinafore*, Act I.

and H. N. Fisk which so profoundly affected his ensuing scientific endeavors. During these years, he also developed the great and unselfish love of Louisiana State University, which, in later years, became almost a passionate devotion.

As an undergraduate Slick entered wholeheartedly into collegiate life and affairs. A member of Sigma Nu (Commander, 1940–41), Samurai, Geological and Mining Society of American Universities, and other organizations, he was selected president of the Men's Interfraternity Council (1940–41) and of the Interfraternity Athletic Association (1939–40). In Who's Who Among Students in American Universities and Colleges (1940 41) he listed music as his hobby.

Requirements for the Bachelor of Science were completed in June, 1940, and Slick commenced graduate work immediately. During the summer of 1940, along with other students, he assisted me in a Louisiana Geological Survey project of surface mapping in DeSoto and Red River Parishes, Louisiana. The spirits of the entire field party were uplifted more or less continuously by Slick's good humor and by his ever-readiness to render either parts or all of any of Gilbert and Sullivan's operettas. *The Mikado* and *The Pirates of Penzance* were his favorites at this time, and many were the hours we listened to:

On a tree by a river a little tom-tit
Sang "Willow, titwillow, titwillow!"
And I said to him, "Dicky-bird, why do you sit
Singing 'Willow, titwillow, titwillow'?"
"Is it weakness of intellect, birdie?" I cried,
"Or a rather tough worm in your little inside?"
With a shake of his poor little head, he replied,
"Oh, willow, titwillow, titwillow!"[2]

During the academic years 1940–42, Slick and Richard Wasem devoted research time to a study of the fauna and stratigraphy of the Wilcox Pendleton formation (lower Eocene) of western Louisiana. In the summer of 1941, active field work in the area of their interest was done with H. N. Fisk for the Brown-Woods Oil Corporation. The paleontologic results of these studies were submitted by Wilbert to the Department of Geology at L.S.U. as a Master's thesis entitled, "Faunal zones in the Pendleton formation." And the Master of Science degree was conferred on him in June, 1942. In the last year of his study at L.S.U. he was a graduate teaching assistant in the Department of Geology.

Louis entered the U. S. Army Air Force as an aviation cadet shortly after this graduation and served until January, 1946. He rose from cadet to the rank of Major in communications. His main posts were at Ascension Island and Natal, Brazil.

On his release from the armed services, Slick sought the advice and counsel of H. V. Howe and H. N. Fisk concerning his future plans and, as a result, matriculated at the University of Kansas for study toward the doctorate under R. C. Moore. At the suggestion of Fisk, he chose as a dissertation object the Jacksonian deposits of southeastern Arkansas. Through the guiding hand of Moore, he came up with a most fundamental contribution to the Tertiary stratigraphy of the Mississippi Embayment. The results of this study were accepted by the University of Kansas faculty as a dissertation and the degree of Doctor of Philosophy was conferred on Slick by that institution in June, 1951.

During the years 1946–1949, he served variously as a teaching assistant at Kansas and as an instructor at L.S.U. As a result of his professional development, he was promoted to assistant professor on the L.S.U. faculty in 1949, and retained that rank until his resignation in May, 1952. At the time of his resignation, recommendation for promotion to associate professor was in process.

He was married to Nancy Jane Kilpatrick in July, 1947, and to her must go credit for inspiration and comfort during his doctoral studies. One child, Nancy Jane, was born in May, 1948.

Condensed results of Wilbert's doctoral researches were presented to the First Annual Meeting of the Gulf Coast Association of Geological Societies both orally and in printed form in 1951. Complete results of these studies have been published by the Arkansas Geological Survey as Bulletin No. 19 entitled "The Jacksonian Stage in Southeastern Arkansas."

The rigorous mental exercises occasioned by the stratigraphic complexities of these Jacksonian deposits and by the disciplines of R. C. Moore developed in Slick an insatia-

[2] Gilbert and Sullivan, *The Mikado*, Act II.

bility for scientific truth and accuracy and an ambition to obtain ever increasing knowledge of the Tertiary of the North American Coastal Plain. They resulted, further, in strenuous devotion to details in both the classroom, laboratory, and field. It may be said that Wilbert was a strict disciplinarian, personally as well as professionally, and expected high achievements of both his students and geological associates. At the same time, he was respected and admired by students and contemporaries alike, even by those who could not meet his standards. He had little time for the incompetents, but would devote unceasing efforts to the able and energetic. His continual efforts to improve standards and calibre of work in the department at L.S.U. shall be sorely missed.

> At this juncture I may mention
> That this erudition sham
> Is but classical pretension,
> The result of steady "cram":
> Periphrastic methods spurning,
> To this audience discerning
> I admit this show of learning
> Is the fruit of steady "cram!"[3]

In this connection, Slick's attitude concerning superficiality and irrelevant details, and his continuous efforts to segregate fact from fancy are well echoed by the passage he quoted so often:

> Merely corroborative detail, intended to give artistic versimilitude to an otherwise bald and unconvincing narrative.[4]

The period 1949–52 witnessed ever greater interest by him in stratigraphy and the applications of paleontology, even though considerable of his time was devoted to consulting work, occasioned by the continuing illness of his wife, stricken with bulbar poliomyelitis in August, 1949. From September, 1950 to June, 1952, he collaborated with H. N. Fisk and C. R. Kolb as consultants for the Mississippi River Commission in a study of the Atchafalaya River. During this same period, and until his death, he was consultant for the TVA as well as for various firms and individuals.

In June, 1951, Wilbert was appointed by T. H. Philpott as Co-editor of the Journal of Paleontology for the Society of Economic Paleontologists and Mineralogists. Standards maintained by the Journal during this year reflect measurably his efforts and policies.

He resigned his position at the University in May, 1952, to enter private business with his father-in-law, A. K. Kilpatrick, in Monroe, Louisiana, and to engage in private consulting. He continued in this work until his death.

Wilbert was a member of Phi Kappa Phi, Sigma Xi, Sigma Gamma Epsilon, Geological and Mining Society of American Universities, American Association of Petroleum Geologists, Society of Economic Paleontologists and Mineralogists, Geological Society of America, American Geophysical Union and Society for the Study of Evolution. He is listed in Leaders in American Science. He belonged also to the Sigma Nu fraternity and was a devout member of St. John the Evangelist Catholic Church of Plaquemine, Louisiana.

He is survived by his wife, the former Nancy Jane Kilpatrick, Polio Ward, Charity Hospital, New Orleans, Louisiana; and daughter, Nancy Jane, Plaquemine and Monroe, Louisiana. A sister, Mrs. Bert S. Turner, resides in Baton Rouge, Louisiana; a brother, William Pope, and both parents live in Plaquemine.

Louis Joseph Wilbert, Jr., was an energetic and continuous worker, of varied interests and virtually unlimited ability. It was his considered judgement that all men should know the world in which they live—geologically, artistically, religiously, politically, and so on—and should partake of all. A devotee of fine music, Slick was especially fond of Gilbert and Sullivan. He often said that their passages contained verse apropos to any occasion in life. Seldom was he stumped by requests to prove his point.

Held in esteem by his professional colleagues, admired by his friends and associates for his moral courage and fiber, and liked by all who permitted themselves to know him, Slick rests a monument to those who molded him so well in life—his parents, Louis Joseph, Sr., and Gertrude Pope; Henry V. Howe; Harold N. Fisk; Raymond C. Moore; and his wife, Nancy Kilpatrick Wilbert.

[3] Gilbert and Sullivan, *The Grand Duke*, Act II.
[4] Gilbert and Sullivan, *The Mikado*, Act II.

He was my friend.

I am the very model of a modern Major-General,
I've information vegetable, animal, and mineral,
I know the kings of England, and I quote the fights historical,
From Marathon to Waterloo, in order categorical;
I'm very well acquainted too with matters mathematical,
I understand equations, both the simple and quadratical,
About binomial theorem I'm teeming with a lot o' news—
With many cheerful facts about the square of the hypotenuse.[5]

GROVER E. MURRAY
Louisiana State University
Baton Rouge, Louisiana
June 26, 1953

[5] Gilbert and Sullivan, *Pirates of Penzance*, Act I.

LIST OF PUBLICATIONS
LOUIS J. WILBERT, JR.

1943 (with Richard Wasem), The Pendleton formation, Louisiana and Texas: Jour. Paleontology, vol. 17, pp. 181–195.

1950 (with Grover E. Murray), The Jacksonian Stage: Bull. American Association Petroleum Geologists, vol. 34, pp. 1990–1997.

1951 Faunas and facies in the upper Eocene of Arkansas: Bull. of First Annual Meeting, Gulf Coast Association of Geological Societies, pp. 122–133.

1952 (with H. N. Fisk and Charles R. Kolb), Geologic investigation of the Atchafalaya River Basin and the problem of Mississippi River diversion: Special Report, U. S. Engineers, Waterways Experiment Station, 2 volumes.

1952 (with Grover E. Murray and A. Scott Warthin, Jr.), Editor, Journal of Paleontology, Volume 26, 6 numbers, 1011 pages.

1953 Jacksonian Stage in southeastern Arkansas: Arkansas Geological Survey Bull. No. 19.

1953 (with H. N. Fisk, E. McFarlan, Jr., and C. R. Kolb), Sedimentary framework of the modern Mississippi Delta (abstract): Jour. Sedimentary Petrology, vol. 23, p. 132.

JOURNAL OF PALEONTOLOGY, VOL. 27, NO. 4, P. 623, JULY 1953

NOTICES

The American Geological Institute through the good offices of its member societies and the editors of geological journals is beginning a compilation of geological abstracts. The first issue will cover January to June 1953, and will be circulated to subscribers about July 15. Thereafter the issue will be quarterly scheduled as March 30, June 30, September 30, and December 30, of each year.

The subscription price will not exceed $2.00 per year. So that the editors may anticipate printing requirements, will all geologists interested in subscribing to the new service, send a postal card at once to: American Geological Institute, 2101 Constitution Avenue, N. W., Washington 25, D. C. *Do not send any subscription money now!*

NEWS AND EVENTS

Effective with this issue the S.E.P.M. institutes in its issues a regular section of news and events.

The Mid-Continent regional meeting of the American Association of Petroleum Geologists will be held in the Masonic Building in Wichita, Kansas, from September 30 to October 2, 1953.

The South Texas Geological Society will conduct a two-day field trip October 30–31, 1953, in the Kerr Basin and Edwards Plateau area between San Antonio and Del Rio, Texas. Primary objective of the trip will be study of the Cretaceous sediments in this area. Details of the trip may be procured from Mr. F. M. McClain, Secretary, South Texas Geological Society, c/o George H. Coates, 638 Milam Bldg., San Antonio, Texas.

WYOMING GEOLOGICAL ASSOCIATION EIGHTH ANNUAL FIELD CONFERENCE

The Wyoming Geological Association will holds its Eighth Annual Field Conference at Laramie, Wyoming, and vicinity on Thursday, Friday, and Saturday, July 30, 31, and August 1. The educational nature of the conference is such that the University of Wyoming has kindly consented to act as host and make available its facilities for conference purposes. Daily field trips will be conducted in the Laramie Basin of Wyoming, and the North Park Basin of Colorado. Registration will be held on the campus on the afternoon of July 29.

The geomorphology of the Medicine Bow Mountain Range, the structural relations of the Medicine Bow Mountains to the Laramie Basin and the sedimentary structures of the Fountain and Casper formations of the southern Laramie Basin will be studied in the field on the first day of the conference.

The second day will be devoted principally to oil fields. Essentially every oil field in the Laramie Basin will be visited. The world famous dinosaur locality at Como Bluff will also be visited.

The last day's trip will be concerned with the structure and stratigraphy of the North Park Basin in north-central Colorado.

BILLINGS GEOLOGICAL SOCIETY FOURTH ANNUAL FIELD CONFERENCE

The Billings Geological Society of Billings, Montana, will holds its fourth annual field conference during the first part of September, in the Little Rocky Mountain area of north-central Montana. Headquarters and registration will be at Zortman, Montana.

Two full days will be given to the study of several excellent Little Rocky Mountain sections extending from the pre-Cambrian upward to the Upper Cretaceous. This will include the type locality for the Lower Mississippian.

Because of lack of adequate housing facilities, the Society plans to establish a field camp near Zortman. All persons attending will be required to bring sleeping bags. Due to inadequate accommodations, the Society encourages the registration of men only, with participation limited to 200.

JOURNAL OF PALEONTOLOGY, VOL. 27, NO. 4, PP. 624–632, JULY 1953

SOCIETY RECORDS AND ACTIVITIES

REPORTS AND MINUTES OF THE TWENTY-SEVENTH ANNUAL MEETING OF THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

The twenty-seventh annual meeting of the Society of Economic Paleontologists and Mineralogists was held in the Coliseum in Houston, Texas, March 23–26, 1953, in conjunction with the annual meeting of The American Association of Petroleum Geologists.

The Presidential Address of the Society, "Foraminifera, an evaluation," was given by Clifford C. Church in the joint session on Tuesday, March 24.

The first part of the technical program of the Society, with Henry W. Menard, Jr., and F. W. Rolshausen presiding, was held in the Corral Room from 2:00 to 5:00 P.M., Tuesday, March 24. The following symposium was presented.

FINDING ANCIENT SHORELINES

Howard R. Gould and Robert H. Stewart, "Continental shelf sediments off the west coast of Florida"

P. C. Scruton, "Distribution and origin of sediment units in the eastern Mississippi delta"

Warren C. Thompson, "Shorelines of the Atchafalaya region, Louisiana"

Francis P. Shepard and David G. Moore, "Sediment zones bordering the barrier islands of the central Texas coast"

Alan Lohse, "Dynamic geology of the modern coastal region, northwest Gulf of Mexico"

D. L. Inman and T. K. Chamberlain, "Particle-size distribution in nearshore environments"

JOINT AAPG-SEPM-SEG SESSION

The following papers were presented in the joint session from 9:00 A.M. to 12:00 noon, Wednesday, March 25, with Clifford C. Church presiding.

Heinz A. Lowenstam, "Application of new techniques to basic objectives in paleontology"

Loy M. Charter, "Some recent developments in well logging"

W. C. Krumbein and L. L. Sloss, "Environmental interpretation of facies maps"

Henry Cortes, "Geophysical progress"

N. C. Steenland, "Aeromagnetic anomalies over known structures and oil fields"

D. W. Rockwell, "Seismograms as an aid to geological interpretation in the Poza Rica area"

GENERAL SESSIONS

The following papers were presented in a general session from 2:00 to 5:00 P.M., Wednesday, March 25, with Charles W. Stuckey, Jr., and Alva C. Ellisor presiding.

W. T. Rothwell, "Age or biofacies correlation in petroleum geology"

V. Petters, "Development of Upper Cretaceous foraminiferal faunas in Colombia, S. A."

Esther R. Applin, "The 'Barlow Fauna,' a biofacies of the early Upper Cretaceous lower Atkinson formation in the southeast Gulf Coast"

Harbans S. Puri, "Zonation of the Ocala group in peninsular Florida"

Harbans S. Puri, "Reclassification of the Miocene of the Florida panhandle"

Harold V. Andersen, "The ostracode genus *Machaerina* and its ecological implications in the study of the mudlump sediments"

Louis de A. Gimbrede, "Hurricane lentil Eocene Foraminifera"

M. K. Elias, "Illustrated report on the Algiers International Geological Congress"

In a session from 9:00 A.M. to 12:00 noon, with Sherman A. Wengerd and W. T. Rothwell presiding, the following papers were read.

L. L. Sloss and W. C. Krumbein, "Faunas, facies, and tectonics"

H. N. Fisk, E. McFarlan, Jr., C. R. Kolb, and L. J. Wilbert, Jr. (presented by E. McFarlan, Jr.), "Sedimentary framework of the modern Mississippi delta"

Charles C. Bates, "A rational theory of delta formation as exemplified by the present-day Mississippi delta"

R. H. Nanz, "Nature and origin of an Oligocene sandstone reservoir"

John W. Harrington, James K. Liles, Edward L. Hazelwood, Lane E. Horstman, Howard E. Jacks, and Neal Neese, Jr., "Down-wind clastic limestones as a key to the location of buried reef knolls"

J. K. Rigby, "Subaqueous landslides and turbidity currents in the Permian of west Texas"

S. W. Lowman and R. F. Beers, "Origin of the Deepkill shale"

The following papers were presented in a session from 2:00 to 4:00 P.M., Thursday, March 26, with W. C. Krumbein and Gordon Rittenhouse presiding.

E. C. Dapples and H. A. Slack, "Petrophysics of the St. Peter-Simpson formations"

Raymond Sidwell and G. F. Warn, "Diagenesis of some Pennsylvanian limestones of New Mexico"

G. F. Warn and Raymond Sidwell, "Diagenesis of some Pennsylvanian sandstones of New Mexico"

Paul Edwin Potter and Jerry S. Olson, "The direction of sediment transport of the basal Pennsylvanian sandstones of Indiana and southern Illinois"

Raymond Siever, "Petrogenesis of Lower Pennsylvanian sandstones of the Eastern Interior Basin"

The meeting adjourned at 4:00 P.M.

ANNUAL BUSINESS MEETING

The annual business session of the Society was called to order at 4:00 P.M., Thursday, March 26, by Clifford C. Church, president.

It was moved by Raymond C. Moore, seconded by Jack Hough, and approved that the minutes of the 1952 meeting be approved as published in the *Journal of Paleontology*, vol. 26, no. 4 (July, 1952).

The following reports were given.

1. *Report of the Editors of the Journal of Paleontology* (*Grover E. Murray and Louis J. Wilbert, Jr.*).—Volume 26 of the *Journal of Paleontology*, issued in conjunction with the Paleontological Society in 1952, contains 1016 pages and 135 collotype plates. Published in it are 64 papers; 2 bibliographies and indexes of Foraminifera; a symposium on distribution of evolutionary explosions in geologic time containing 6 papers and discussion; one article on techniques; 15 paleontological notes; 10 nomenclatural notes; and miscellaneous notices, reviews, and Society records.

Volume 26 represents an increase of 187 pages and 17 collotype plates over volume 25. Comparative sizes of individual volumes since 1940, broken down into P.S. and S.E.P.M. fractions, are attached for comparison.

The March, July, and November numbers were prepared by your editors on behalf of the Society of Economic Paleontologists and Mineralogists. These numbers consist of 476 pages and 50 collotype plates, an increase of 102 pages and 5 plates over the previous volume. Because the number of manuscripts on hand at the beginning of the year were sufficient to fill out all 1952 numbers, thereby meaning at least a year's delay in publication, the 1952 issues were increased to 160 pages. This policy has decreased the backlog enough that publication can now be guaranteed in 3–6 months.

Financially, this policy of reducing the backlog of papers on hand, together with certain cost increases, resulted in the editors exceeding the allotted budget for the year. This deficit was reduced to some extent by assistance provided by Louisiana State University in defraying part of the cost of an editorial assistant and all the costs of miscellaneous supplies and expenses involved in editing. Part of the deficit may be recouped in 1953 by smaller sized issues, although price increases in engraving, effective March, 1953, will partially offset any reduction in size. Increased advertising appears to offer one of the best solutions for increased income.

The March, July, and November issues contain contributions which may be classified as given at the top of the next page.

Four of these papers are concerned with fossils outside of North America. In addition, there are two bibliographies and indexes of Foraminifera; four papers on phylogeny and taxonomy; an article on paleontological comparisons; ten paleontological notes; four nomenclatural notes; one review; miscellaneous notices, errata, Society records and activities; and an author and subject index.

Policy-wise, your editors have (1) re-

	Paleo-zoic	*Meso-zoic*	*Ceno-zoic*	*Mis-cella-neous*	*To-tals*
Algae.....			1		1
Diatoms.....			1		1
Foraminifera.	1		3	2	6
Crinoids.....	1				1
Brachiopods..	1				1
Cephalopods .	2	3		1	6
Trilobites....	2			2	4
Ostracoda....	3		3		6
Malacostraca.				1	1
Conodonts...	3	1			4
TOTALS....	13	4	8	6	31

turned or exchanged papers submitted to them on vertebrate paleontology, since they are considered of limited interest to economic paleontologists; (2) given priority to those papers which appear to be most timely and to be of greatest economic pertinency; (3) encouraged authors to include geographic and stratigraphic data related to their problem, thereby earning a greater number of readers; and (4) where possible, encouraged authors to use line drawings to illustrate morphological or stratigraphical features discussed in their articles.

Considerable time was devoted during the past year to (1) discussions with the Paleontological Society concerning publication costs and related items, and (2) developing and formulating plans for the publication of an index of the first 25 volumes of the *Journal*. Cost estimates have been obtained from letter-press and lithoprinting companies and present plans call for publication of the index in late 1953 or early 1954.

The assembly was advised that *Journal of Paleontology* Co-Editor Louis J. Wilbert, Jr., had been killed in an auto accident a few days before and that a wreath had been sent in the name of the S.E.P.M.

2. *Report of the Editor of the Journal of Sedimentary Petrology* (*Jack L. Hough*).—The *Journal of Sedimentary Petrology* was published in 1952 as volume 22, numbers 1 through 4. Number 1 contains 60 pages and numbers 2 through 4 contain 64 pages each, the authorized maximum. Thirteen hundred copies of each issue were printed. The contents of the volume include 24 technical articles, 2 notes, 2 discussions, 2 reviews, 5 announcements and an index. Six one-half page advertisements of Society publications were run, and two one-half page paid advertisements were run.

The distribution of articles and notes according to national origin was as follows: United States, 23½; Netherlands, 1½; Germany, 1; Egypt, 1; and Australia, 1.

The size of the *Journal* has continued to be in good adjustment to the number of papers accepted for publication; the average back-log has been an eight-months' supply of papers.

The income from membership dues assigned to the *Journal* and from subscriptions has again exceeded the cost of production of the *Journal*. As in the past three years, the University of Illinois has provided a half-time editorial assistant.

Special Publication No. 2 of the Society, *Turbidity Currents and the Transportation of Coarse Sediments to Deep Water—A Symposium*, which was published in 1951, and which had more than paid for itself during the first

COMPARISON OF NUMBER OF PAGES AND PLATES PUBLISHED BY THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND PALEONTOLOGICAL SOCIETY SINCE 1940

Year	PAGES S.E.P.M.	PAGES P.S.	PAGES Total	PLATES S.E.P.M.	PLATES P.S.	PLATES Total
1952.....	476	540	1,016	50	85	135
1951.....	378	451	829	45	73	118
1950.....	402	360	762	39	51	90
1949.....	372	328	700	45	58	103
1948.....	483	330	813	60	64	124
1947.....	333	270	603	36	48	84
1946.....	321	312	633	45	45	90
1945.....	304	360	664	42	46	88
1944.....	317	248	565	49	44	93
1943.....	280	361	641	39	70	109
1942.....	393	400	793	48	70	118
1941.....	349	358	707	29	56	85
1940.....	293	329	622	40	29	69

year, has made a total profit of $836.50 as of December 31, 1952.

3. *Report of the Secretary-Treasurer* (*Cecil G. Lalicker*).—

BACK VOLUME SALES
(March 1, 1952 to March 1, 1953)

Back volumes of the *Journal of Paleontology*	$4,378.80
Back volumes of the *Journal of Sedimentary Petrology*	943.10

SPECIAL PUBLICATION SALES
(March 1, 1952 to March 1, 1953)

Turbidity Currents	$ 321.55

PRINTING AND ENGRAVING BILLS FOR 1952
Journal of Paleontology

	Banta Printing Bills	*Meriden Engraving Bills*	*Total Printing and Engraving Bills*	*S.E.P.M. Total Printing and Engraving Bills*
Number 1 (January)*	$ 2,052.16	$ 952.12	$ 3,004.28	
Number 2 (March)	2,584.13	671.00	3,255.13	$3,255.13
Number 3 (May)*	3,465.79	796.40	4,262.19	
Number 4 (July)	2,465.11	882.48	3,347.59	3,347.59
Number 5 (September)*	2,648.88	1,502.05	4,150.93	
Number 6 (November)	2,486.75	374.45	2,861.20	2,861.20
	$15,702.82	$5,178.50	$20,881.32	$9,463.92
(1951 Totals)	($11,756.76)	($3,974.21)	($15,730.97)	($7,127.41)

* Odd numbers paid by Paleontological Society.

Journal of Sedimentary Petrology

Number 1 (March)	$ 953.10
Number 2 (June)	1,105.98
Number 3 (September)	1,061.78
Number 4 (December)	961.30
	$4,082.16
(1951 Total)	($3,678.50)

MEMBERSHIP, MAILING, AND JOURNAL STATISTICS

	March 1953	*March 1952*	*March 1951*
1. S.E.P.M. Membership:			
Active Members	618	583	563
Associates	310	288	229
Honorary Members	1	1	1
Correspondents	5	5	5
TOTAL	934	877	798
2. *Journal of Paleontology* Mailing List:			
S.E.P.M. Active Members	382	373	362
S.E.P.M. Associates	181	167	130
Subscribers	568	538	519
P.S. Members	573	511	443
TOTAL	1,704	1,589	1,454
3. *Journal of Sedimentary Petrology* Mailing List:			
S.E.P.M. Active Members	385	331	337
S.E.P.M. Associates	189	170	133
S.E.P.M. Correspondents	5	5	5
Subscribers	541	489	449
TOTAL	1,120	995	924

4. Number of pages in 1952 *Journal of Paleontology*	1,016 (829, 1951)
5. Number of plates in 1952 *Journal of Paleontology*	135 (118, 1951)
6. Total edition of 1952 *Journal of Paleontology*	1,900 (1,800, 1951)
7. Number of pages in 1952 *Journal of Sedimentary Petrology*	244 (241, 1951)
8. Total edition of 1952 *Journal of Sedimentary Petrology*	1,300 (1,200, 1951)
New Members from March 1, 1952, to March 1, 1953	43 (40, 1951–1952)
New Associates from March 1, 1952 to March 1, 1953	40 (78, 1951–1952)
Transfers to Active Membership, March 1, 1952, to March 1, 1953	7 (1, 1951–1952)

FINANCIAL STATEMENT FOR THE YEAR ENDED DECEMBER 31, 1952

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
CERTIFICATE OF CERTIFIED PUBLIC ACCOUNTANTS

To the Council, Society of Economic Paleontologists and Mineralogists:

We have examined the balance sheet of Society of Economic Paleontologists and Mineralogists at December 31, 1952, and the related statement of income and surplus for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying balance sheet and statement of income and surplus present fairly the financial position of Society of Economic Paleontologists and Mineralogists at December 31, 1952, and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

ARTHUR YOUNG & COMPANY

Tulsa, Oklahoma, January 30, 1953

BALANCE SHEET AT DECEMBER 31, 1952

ASSETS	*Total*	*General Fund*	*Publication Fund*
CURRENT ASSETS:			
Cash	$10,979.39	$10,191.89	$ 787.50
Savings account	2,457.34	2,457.34	—
Accounts receivable (less reserve, $40.75)	1,446.54	1,438.29	8.25
Total current assets	$14,883.27	$14,087.52	$ 795.75
PUBLICATIONS:			
Journal of Paleontology:			
Issues prior to 1952—15,938 journals at $.50 each (2,583 complete volumes)	$ 7,969.00	$ 7,969.00	$ —
Issues 1 to 6 of 1952—864 journals, at cost	1,613.73	1,613.73	—
Reprints in 1948, Volume 1, 1927—789 volumes, at cost	1,733.24	1,733.24	—
Journal of Sedimentary Petrology:			
Issues prior to 1952—2,654 journals at $.50 each (802 complete volumes)	1,327.00	1,327.00	—
Issues 1 to 4 of 1952—560 journals, at cost	464.21	464.21	—
Special publications:			
Turbidity Currents, 758 issues, at cost	648.17	—	648.17
Total publications	$13,755.35	$13,107.18	$ 648.17
FURNITURE AND FIXTURES (less reserve, $1,104.18)	$ 1.00	$ 1.00	$ —
DEFERRED CHARGES	$ 494.15	$ 494.15	$ —
	$29,133.77	$27,689.85	$1,443.92
LIABILITIES AND SURPLUS			
CURRENT LIABILITIES:			
Accounts payable	$ 2,529.05	$ 2,529.05	$ —
Amount payable to Paleontological Society	3,098.87	3,098.87	—
Accrued printer's charges	1,000.00	1,000.00	—
Total current liabilities	$ 6,627.92	$ 6,627.92	$ —

DEFERRED CREDITS:			
Subscriptions to journals (less $1,389.43 payable to Paleontological Society	$ 3,813.75	$ 3,813.75	$ —
Membership dues for 1953 and 1954	3,654.10	3,654.10	—
Total deferred credits	$ 7,467.85	$ 7,467.85	$ —
SURPLUS (per accompanying statement)	$15,038.00	$13,594.08	$1,443.92
	$29,133.77	$27,689.85	$1,443.92

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
STATEMENT OF INCOME AND SURPLUS
FOR THE YEAR ENDED DECEMBER 31, 1952

	Total	*General Fund*	*Publication Fund*
INCOME:			
Membership dues and subscriptions:			
Journals of Paleontology and Sedimentary Petrology	$ 2,389.40	$ 2,389.40	$ —
Journal of Paleontology	8,106.82	8,106.82	—
Journal of Sedimentary Petrology	4,231.43	4,231.43	—
	$14,727.65	$14,727.65	$ —
Sales of special publication—Turbidity Currents	$ 460.20	$ —	$ 460.20
Sales of back numbers:			
Journal of Paleontology, Volume 1, 1927	$ 176.90	$ 176.90	$ —
Journal of Paleontology, Volumes 2 to 26	4,528.20	4,528.20	—
Journal of Sedimentary Petrology	1,154.00	1,154.00	—
	$ 5,859.10	$ 5,859.10	$ —
Plates	$ 340.76	$ 340.76	$ —
Advertising	$ 140.00	$ 140.00	$ —
Donations ($1,000 from A.A.P.G.)	$ 1,150.00	$ 1,150.00	$ —
Miscellaneous	$ 237.50	$ 237.50	$ —
	$22,915.21	$22,455.01	$ 460.20
Less: Proportion of 1952 income accrued to Paleontological Society	2,935.86	2,935.86	—
	$19,979.35	$19,519.15	$ 460.20
COSTS AND EXPENSES:			
Cost of printing:			
Journal of Paleontology	$ 9,787.23	$ 9,787.23	$ —
Journal of Sedimentary Petrology	4,045.59	4,045.59	—
	$13,832.82	$13,832.82	$ —
EXPENSES			
Clerical salaries	$ 3,295.00	$ 3,295.00	$ —
Employee pension and death benefits plan	273.99	273.99	—
Office supplies	648.48	648.48	—
Postage and express	892.84	892.84	--
Office rent	768.00	768.00	—
Telephone	168.48	168.48	—
Audit fee	200.00	200.00	—
Payroll taxes	138.44	138.44	—
Miscellaneous	446.47	387.53	58.94
	$ 6,831.70	$ 6,772.76	$ 58.94

Adjustment for decrease in inventory of publications.....	$ 948.72	$ 781.98	$ 166.74
	$21,613.24	$21,387.56	$ 225.68
NET INCOME (LOSS).....	$(1,633.89)	$(1,868.41)	$ 234.52
SURPLUS AT DECEMBER 31, 1951.....	16,671.89	15,462.49	1,209.40
SURPLUS AT DECEMBER 31, 1952.....	$15,038.00	$13,594.08	$1,443.92

4. *Report of the Research Committee (Henry W. Menard, Jr., Chairman—Read by E. C. Dapples).*—The activities of the Research Committee (composed of E. C. Dapples, Grover E. Murray, F. W. Rolshausen, J. F. Rominger, vice-chairman, and Henry W. Menard, Jr., chairman) in 1952–53 were focused on organizing a symposium for the meeting in Houston, and on establishing a system of awards to be given by the Society for the best papers published in the Society *Journals*. The editors of the *Journals* published an announcement of the awards and a ballot in the respective year-end issues, and the Society members were invited to vote. A small number did so,—less than twenty for each *Journal*. This disappointing result was not wholly unexpected and is not thought to indicate a total lack of interest by Society members. Inquiry has shown that many members do not know of the proposed awards, and of those who do many did not see the printed announcement and ballot. Others were reluctant to deface the *Journals* by cutting out the ballots, and, of course, the majority of those interested never quite got around to voting. The habit of voting surely will grow in a few years and all members will at least become aware of the awards so we may anticipate better results in the future.

Suggestions of the various Committee members resulted in the selection of "Finding Ancient Shorelines" as the topic of a symposium. Somewhat more than a hundred letters later the symposium was organized with six speakers and a panel of seven discussants or commenters. The Committee is indebted to E. L. Hamilton, F. P. Shepard, and M. B. Stephenson for their invaluable help in organizing this symposium.

Rominger acted as Committee representative in helping to organize an A.A.P.G. symposium on new methods in oil finding. He prevailed upon Heinz Lowenstam to speak on the topic "The Application of New Techniques to the Basic Objectives of Paleontology."

It was moved by W. C. Krumbein, seconded by H. A. Ireland, and approved that the foregoing reports be accepted.

5. *Report on the A.G.I. (W. C. Krumbein, Director).*—The Directors of the American Geological Institute met at Boston during the 1952 G.S.A. meetings and at Houston during the 1953 A.A.P.G. convention. A problem of considerable importance involved the replacement of Dr. Delo as Executive Secretary. Dr. R. W. Webb assumed the position while on leave from Santa Barbara College and will remain at least until fall. Definite progress was reported on the Glossary, prepared under the chairmanship of J. V. Howell, and supported by a joint grant from the G.S.A. and the National Science Foundation. An abstracts journal is also well under way and the first issue may appear during 1953. By far the greatest emphasis is being placed on manpower problems, however, and the A.G.I. is represented on the National Manpower Commission, a group similar to the Engineering Foundation, but representing the physical sciences. It is anticipated that this representation will do much to protect the interests of geologists in the national manpower situation.

R. C. Moore, after being recognized by the chair, made the following statement. "Before leaving the matter of the reports we have heard, I believe it is quite proper that we as a body should take cognizance of the unselfish labor which is represented. I know, on behalf of the president, secretary-treasurer, and other officers, we owe much for the work which has been done. I would like to offer a motion thanking these gentlemen for their service to the Society during the year and in doing so I think we should be remiss if we did not make a special record of the death of our editor, Louis Wilbert, and that that should be a part of our action." Motion

was seconded by M. A. Hanna and unanimously approved.

6. *Report of the Pacific Section (W. Thomas Rothwell, Jr.)*—The Pacific Section is now headed by Professor Orville Bandy of the University of Southern California and several field trips have been organized. The Section wishes to extend its greetings to the national Society.

7. *Presidential Summary (Clifford C. Church)*.—During the past year, 1952–53, the Society roster of new members has continued to grow. To date we have forty-five new active members, twenty-five associate members, and two transfers from associate to active membership, in all seventy new members. This does not account for losses of old members.

The sale of back numbers of our two *Journals* and the special publication, *Turbidity Currents*, has continued to be good. Within the past few months your Council has arranged for publication of a species, genus, and subject index of the first 25 volumes of the *Journal of Paleontology*. This is being done with the cooperation of the Paleontological Society. The work of assembling the index has been undertaken by Hans Thalmann of Stanford University. Some of the indexing was completed a few years ago with the assistance of Wolf Maync and in the present work he will be assisted by J. J. Graham, also of Stanford University. It is hoped that the index will be out by the end of the year.

The symposium for this year's meeting, "Finding Ancient Shorelines," will be published as an S.E.P.M. Special Publication during 1953. Jack L. Hough has been appointed editor. It is also probable that abstracts of papers given at the annual meetings will hereafter be published in the June issue of the *Journal of Sedimentary Petrology*.

A new project of the A.A.P.G., in which the S.E.P.M. has had a part, is the newly formed Advisory Committee on Radioactive Mineral Exploration. J. Harlan Johnson and John Emery Adams were our representatives. Mr. Adams asked to be relieved of his duties when he was elected president of the A.A.P.G.

At the International Geological Congress held in Algiers we were represented by M. K. Elias whose report you have heard. W. C. Krumbein was our representative at the A.G.I. meeting in Boston and Grover E. Murray acted in the same capacity for T. H. Philpott. Dr. Krumbein has also been appointed a member of the National Research Council to represent the S.E.P.M. for the period July 1, 1952, to June 30, 1955. Willard D. Pye of the North Dakota Agricultural College was appointed our representative on the A.G.I. Steering Committee on a Glossary of Geologic Terms. At the fourth International Congress of INQUA (International Association for the Study of the Quaternary) to be held at Rome-Pisa, Italy, August 30 to September 10, 1953, Ramiro Fabiani of the Institute of Geology and Paleontology of the University of Rome will be our representative. For the Houston meeting our vice-president, M. B. Stephenson, was our very able program chairman, and J. F. Rominger, vice-chairman of the Research Committee.

An incident new to the history of the Society was the resignation of the president-elect, J Marvin Weller. Dr. Weller received an assignment to the Philippines after the ballots were mailed. As he will be away for two years, he felt that it would be impossible to carry on the duties of president from that distance, so regretfully resigned. This situation brought out the fact that there was no machinery in our present Constitution to take care of this emergency. With that in mind the Council has drawn up an amendment to the By-Laws which can be voted upon at this time. We have asked M. A. Hanna to read the proposed amendment.

Dr. Hanna stated that it has been the understanding of all nominating committees that in the event the president is unable to carry out his duties, the details of that office automatically become the responsibility of the vice-president. It has, therefore, been the practice to nominate a man for vice-president who would be able to carry on capably in an emergency. Dr. Hanna then proposed that Harold N. Fisk, vice-president elect, be installed as the new president of the Society and that the following Article III, Section 3, of the By-Laws be enacted herewith:

3. If, after his election by the regular ballot, the president shall not be able to discharge the

duties of his office, because of death or resignation, the duly elected vice-president shall then assume the duties and title of President with all of the authority vested in him by the Constitution. In the event the vice-president shall not be able to assume said duties, then the succession shall be in the following order: Most recent past-president, second most recent past-president, secretary-treasurer. If none of the above mentioned members of the Council shall be able to assume the office of the President, then a special election shall be held in which at least two qualified members, nominated by the Council, shall be voted upon by the membership by means of a special mailed ballot. Any vacancies in the normally constituted Council caused by such succession may be filled with a temporary appointment by the Council.

Motion was seconded by Stuart Levinson and approved unanimously.

The following was moved by M. A. Hanna and seconded by H. A. Ireland.

It is proposed that the last sentence of By-Laws Article IV, Number 1, which now reads, "In this matter, and in other matters affecting publication policy, the editor or editors will be given the same vote as members of the Council" shall be changed to read, "In this matter, and in other matters affecting publication policy, the editor or editors of the *Journal of Paleontology* and the *Journal of Sedimentary Petrology* shall be members ex-officio of the Council. Each shall have a vote in all matters pertaining to the Society's publications except in regard to the appointment or removal of the editors. In the event there are co-editors of either *Journal*, these co-editors shall have only one vote."

Harold Scott moved that the last sentence of the Amendment to the By-Laws be amended to read "these co-editors shall have one-half vote each." Motion was seconded by R. C. Moore.

The Amendment was then unanimously approved as amended.

It was moved by Jack Hough, seconded by Tom Philpott, and approved that the following resolutions be adopted:

BE IT RESOLVED THAT in behalf of the Society we extend an expression of our sincere thanks to the following.

TO M. B. Stephenson, chairman, and the members of the S.E.P.M. Technical Program for the high quality of the papers secured for the 1953 program;

TO H. W. Menard, Jr., chairman of the Research Committee, and the members of his committee, for the excellent research symposium for the 1953 annual meeting in Houston;

TO Carleton D. Speed, Jr., general chairman of all convention committees, and his vice-chairmen, and the chairmen and members of all convention committees and subcommittees for capable leadership and assistance in organizing and holding the Houston meeting;

TO the Headquarters Hotels, Rice and Shamrock, for providing excellent convention facilities;

TO the City of Houston for the use of the spacious Sam Houston Coliseum and the City Music Hall and its full cooperation at all times.

H. A. Ireland commented that only about 50 members were present, out of a membership of over 900, at the business meeting which should be of importance to the entire Society. He suggested that perhaps it would be better to hold future business meetings earlier in the convention week rather than at the close of the final session. This matter is to be presented to future committees for consideration.

The officers for the new year were announced by outgoing-president, Clifford Church, as follows: President, Harold N. Fisk; Secretary-Treasurer, Samuel P. Ellison, Jr.

The business session adjourned at 5:30 P.M., Thursday, March 26, 1953.